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January 28, 2013

Janet Rosati
Remedial Project Manager
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75 Hawthorne Street (SFD-6-2)
San Francisco, CA 94105

Re: Administrative Order on Consent
U.S. EPA Docket No. 2004-18 (Amended June 5, 2012)
500 South 15th Street Facility, Phoenix, Arizona
Groundwater Flow and Solute Transport Modeling Report
Arcadis (January 24, 2013)

Dear Janet:

Under the captioned Administrative Order on Consent (AOC), Meritor, Inc. (Meritor) and Cooper Industries, LLC (Cooper) are working in a cooperative manner with the Environmental Protection Agency (EPA) Region IX to complete the AOC's terms and conditions for a facility located at 500 South 15th Street in Phoenix, Arizona (Facility). At the time the AOC was initially entered, there were three Respondents: Adobe Air, Inc., Arvin Meritor, Inc. and Cooper Industries, Inc. Respondent Adobe Air, Inc. is no longer a legal entity. ArvinMeritor, Inc. has been replaced by Meritor, Inc. and Cooper Industries, Inc. has been replaced by Cooper Industries, LLC. EPA entered into the AOC Amendment with the two Respondents Meritor and Cooper.

The Facility is within the Operable Unit 3 Study Area of the Motorola 52nd Street Site (Site). The Site was placed on the National Priorities List (NPL) in 1989. Most recently, the Facility has been the subject of a remedial investigation (RI) to determine whether it contributed to Site groundwater contamination and whether there is residual contamination to be addressed.[1]

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[1] SoilVapor Extraction Technical Memorandum, 500 South 15th Street, Phoenix, Arizona, Motorola 52nd Street Superfund Site, from Monika O'Sullivan, Remedial Project Manager to Claire Trombadore, Section Chief (April 12, 2012).

I. THE AOC TERMS – Statement of Purpose.

The Respondents note that the relevant purpose for the parties to initiate the AOC is found on Page 6:

> **IV. STATEMENT OF PURPOSE.**
>
> 8. In entering into this Consent Order, the objectives of EPA and the Respondents are: **(a) to determine the nature and extent of contamination and any threat to the public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants or contaminants at or from this Site, by conducting a focused remedial investigation; (b) to determine and evaluate alternatives for remedial action (if any) to prevent, mitigate or otherwise respond to or remedy any release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a focused feasibility study;** and (c) to recover response costs incurred by EPA with respect to this Site only. **(Emphasis Added).**

The Respondents assert that a "groundwater modeling effort" would be required under the AOC to achieve the identified objectives under (a) and (b) of Paragraph 8. Generally, EPA requires the evaluation of groundwater plume movement and response and supports the modeling of groundwater as a tool to guide site management planning.[2] There are specific requirements under AOC Section X, paragraph 33 which are consistent with the AOC-APPENDIX A/STATEMENT OF WORK-Section 3.3.1 Focused RI/FS Work Plan, which provides on Page 11:

> Because of the unknown nature of the Site and iterative nature of the Focused RI/FS, additional data requirements and analyses may be identified throughout the process. The Respondents will submit a Technical Memorandum documenting the need for additional data requirements to be identified at the request of EPA or as otherwise necessary within twenty (20) days of identification.

The Respondents submitted a Technical Memorandum to EPA dated April 16, 2012, to support the enclosed groundwater modeling effort.

II. AOC – Appendix A/Statement of Work/Focused Remedial Investigation and Feasibility Study.

In review of the AOC – APPENDIX A/STATEMENT OF WORK, it is clear in many sections that a ground water modeling effort is contemplated by the parties in the AOC.

[2] See "A Guide on Remedial Actions for Contaminated Groundwater", USEPA/Solid Waste and Emergency Response (OS220), Directive: 9283.1-2 FS (April 1989); See Also "Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites" OSWER Directive Z983.1-2 (December 1988)

- Under Section 4.0 REMEDIAL INVESTIGATION (p. 14) it provides, "...The Respondents will also investigate the extent of migration of this contamination, including surface and subsurface pathways of migration, as well as its volume and any changes in its physical or chemical characteristics, to provide for a comprehensive understanding of the nature and extent of contamination at the Site. **Using this information, contaminant fate and transport is then considered and projected.....**In view of the unknown site conditions, activities are often iterative, and to satisfy the objectives of the Focused RI/FS it may be necessary for the Respondents to supplement the work specified in the original [Work Plan] WP. As described in Section 3.3.1 [of Attachment B-Summary of Deliverables] this may be done through the submission of Technical Memorandums either initiated by the Respondents or requested by EPA." **(Emphasis Added).**

- Under Section 4.1.4. Nature and Extent of Contamination (p. 16), it states, "In addition, the Respondents will gather data for **calculations of contaminant fate and transport...." (Emphasis Added).**

- Under section 4.2.1. Site Characteristics (p. 17) it provides that, "The Respondents will utilize the results of the site physical characteristics, source characteristics, and the extent of contamination analyses in the **analysis of contaminant fate and transport.** The evaluation will include the actual and potential magnitude of releases from the sources, and horizontal and vertical spread of contamination as well as mobility and persistence of contaminants. **Where modeling is appropriate, Respondents will identify such models to EPA in the Focused RI/FS WP and if necessary, as Supplemented by a Technical Memorandum." (Emphasis Added).**

III. <u>Delivered/Approved Reports</u>.

The Respondents also note that in the "Focused Remedial Investigation Work Plan and Sampling and Analysis Plan" (dated July 19, 2006), which was approved by EPA Comment Letter dated August 3, 2006 under the AOC, it states on Page 1:

> This Focused Remedial Investigation Work Plan and Sampling & Analysis Plan (WP/SAP) has been prepared to outline the rationale and procedures for an environmental investigation to be completed at a manufacturing facility located at 500 South 15th Street, in Phoenix, Arizona (Facility or Site, location shown on Figure 1). The results of the investigation will be used for the following purposes:
>
> - To determine whether or not a release of contaminants of concern (COCs) has occurred. The COCs include: Cloroethane/Ethyl Chloride (CA); 1,1,1-TCA; 1,1,2-Trichloroethane (1,1,2-TCA); 1,1-Dichloroethane (1,1-DCA); 1,2-Dichloroethane (1,2-DCA); tetrachloroethene

(PCE); trichloroethene (TCE); 1,1-Dichloroethylene (1,1-DCE); cis-1,2-Dichloroethylene (cis-1,2-DCE); trans-1,2-Dichloroethylene (trans-1,2-DCE); Vinyl Chloride/Chloroethene (CE); and 1,1-Dioxane.

- **To determine whether any release has significantly contributed to the known groundwater contamination existing in the area of the Site.**

- To determine the location of any of the possible COCs releases.

- If identified, to establish the appropriate steps to mitigate source(s) remaining at the Site, if necessary.

In addition, the Respondents note that in the "Final Phase I Soil Gas Investigation Technical Memorandum – Focused Remedial Investigation" (dated November 9, 2007), which was approved by EPA Comment Letter dated October 12, 2007 under the AOC, it states on Page 1:

1.1 Purpose

"The results of the Focused Remedial Investigation will be used for the following purposes:

- To determine whether or not a release of contaminants of concern (COC) has occurred from the Facility.

. . .

- **To determine the location, nature and extent of any possible COC releases.**

- **To determine whether any identified release from the facility has contributed to the known groundwater contamination existing within the OU-3 portion of the Motorola 52nd Street Superfund Site." (Emphasis Added)**

IV. <u>Conclusion</u>:

It is clear that the AOC Statement of Purpose contemplated some possible groundwater modeling. Although a groundwater fate and transport model report was not a specific deliverable listed under AOC Attachment B-Summary of Deliverables, there are a number of references to contaminant fate and transport or modeling found in AOC <u>APPENDIX A. STATEMENT OF WORK</u>. Many of the Meritor/Cooper supplied deliverables and the EPA approved reports indicate that groundwater modeling is contemplated. The Respondents submitted a Technical Memorandum to EPA dated (April 16, 2012) to support the enclosed groundwater modeling report. The respondents request that EPA review, comment upon and approve the attached document titled "Groundwater Flow and Solute Transport Modeling Report" by Arcadis dated January 24, 2013.

Please contact me with any questions.

Sincerely,

Jerry D. Worsham II

JDW/ac
Enclosures
cc: Linda Furlough, Esq. – Meritor, Inc.
David O'Connor – Meritor, Inc.
Paula Whitten, Esq. – Cooper Industries, LLC
Jing Blailock – Cooper Industries, LLC
Bethany Dreyfus, Esq. – EPA Region IX
John Lucey – EPA Region IX
Rob Mongrain – Arcadis
Brian Stonebrink - ADEQ

Imagine the result

Meritor, Inc.
Cooper Industries, LLC

Groundwater Flow and Solute Transport Modeling Report

500 South 15th Street Facility
Phoenix, Arizona

January 28, 2013

ARCADIS

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EXPIRES 9/30/2015

Robert A. Mongrain, RG
Vice President

Groundwater Flow and Solute Transport Modeling Report

500 South 15th Street Facility,
Phoenix, Arizona

Prepared for:

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Cooper Industries, LLC

Prepared by:

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ARCADIS

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MONGRAIN
DATE SIGNED 01/28/13
ARIZONA U.S.A.
EXPIRES 9/30/2015

1,1-DCA	1,1-Dichloroethane
1,1-DCE	1,1-Dichloroethene
1,1,1-TCA	1,1,1-Trichloroethane
1,2-DCA	1,2-Dichloroethane
1,1,2-TCA	1,1,2-Trichloroethane
cis-1,2-DCE	cis-1,2-Dichloroethene
trans-1,2-DCE	trans-1,2-Dichloroethene
ABC	Aggregate Base Course
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
Amended AOC	Amended Administrative Order on Consent
amsl	Above Mean Sea Level
AOC	Administrative Order on Consent
AWQS	Arizona Water Quality Standards
bgs	Below Ground Surface
CA	Chloroethane
CE	Chloroethene
cfs	Cubic Feet per Second
COCs	Constituents of Concern
COP	City of Phoenix
CPM	Central Phoenix Plume Model
CSM	Conceptual Site Model
C-SVLs	Calculated Soil Vapor Screening Levels
EC	Ethyl Chloride
ESRV	East Salt River Valley
Facility	500 South 15th Street Facility
ft/day	Feet per Day

ARCADIS

FLM	Five Layer Numerical Groundwater Flow Model
FRI	Final Sitewide Focused Remedial Investigation Report
ft	Feet
ft/ft	Feet per Foot
ft^3/day	Cubic Feet per Day
GHBs	General Head Boundaries
GPL	Arizona Groundwater Protection Level
gpm	Gallons per Minute
GWV	Groundwater Vistas
HFB	Horizontal Flow Barriers
IMP	International Metal Products Company
K	Conductivity
Kv	Vertical Conductivity
L/kg	Liters per Kilogram
LAU	Lower Alluvial Unit
MT3DMS	Modular Three-Dimensional Multispecies Transport Model
M52 COCs	Motorola 52^{nd} Street Superfund Site Constituents of Concern
MAU	Middle Alluvial Unit
MCL	Maximum Contaminant Level
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
mg/m^3	Milligrams per Cubic Meter
Non-M52 Constituents	non-Motorola 52^{nd} Street Superfund Site Constituents
NPL	National Priorities List
OM&M	Operation, Maintenance and Monitoring

OU-3	Operable Unit Three
PAP	Phoenix Adobe Partners, LLC
PCE	Tetrachloroethene
RID	Roosevelt Irrigation District
RI/FS	Remedial Investigation/Feasibility Study
RR	Research Report
RSL	Regional Screening Level
SA&B	Scott, Allard & Bohannon
SCFM	Standard Cubic Feet per Minute
SGHHSLs	Soil Gas Human Health Screening Levels
SRLs	Soil Remediation Levels
SRP	Salt River Project
SRV	Salt River Valley
SRVB	Salt River Valley Basin
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leachate Procedure
TLM	Three Layer Numerical Groundwater Flow Model
TMR	Telescopic Mesh Refinement
The Amendment Respondents	Meritor, Inc. and Cooper Industries, LLC
TRC	Tracer Research Corporation
UAU	Upper Alluvial Unit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USTs	Underground Storage Tanks
VC	Vinyl Chloride
VOCs	Volatile Organic Compounds

VWR	Van Waters and Rogers
WSRV	West Salt River Valley
WVB	West Van Buren
WWTP	Waste Water Treatment Plant
µg/L	Micrograms per Liter

1. Introduction

On behalf of Meritor, Inc. and Cooper Industries, LLC (the Amendment Respondents), ARCADIS has prepared this technical report describing a groundwater flow and solute transport model developed for the 500 South 15th Street Facility, in Phoenix, Arizona. The location of the 500 South 15th Street Facility (Facility) is shown on Figure 1. The 500 South 15th Street Facility is located within the Study Area for Operable Unit Three (OU-3) of the Motorola 52nd Street Superfund Site in Phoenix, Arizona (Figure 2). The Motorola 52nd Street Superfund Site was placed on the National Priorities List (NPL) in 1989 and has been identified as a source of groundwater contamination with volatile organic compounds (VOCs); primarily trichloroethene (TCE). The United States Environmental Protection Agency (USEPA) with support from the Arizona Department of Environmental Quality (ADEQ) is overseeing the investigation and remediation activities within the Motorola 52nd Street Superfund Site, including the OU-3 Study Area. USEPA has not yet determined issues of liability in the OU-3 Study Area.

The Respondents are parties to an Administrative Order on Consent (AOC) for Remedial Investigation/Feasibility Study (RI/FS) Docket No. 2004-18 (USEPA, 2004) with the USEPA dated October 13, 2004, as amended on June 5, 2012 (Amended AOC). This Groundwater Flow and Solute Transport Modeling Report has been prepared to meet the Respondent's requirements under the AOC to evaluate the potential nature and extent of contamination in groundwater beneath the Facility and better understand potential contaminant fate and transport. The nature and extent of contamination in soils and soil vapor beneath the site and the resultant risks to human health and the environment (from soil, soil vapor and groundwater) were addressed in the Final Sitewide Focused Remedial Investigation Report (FRI), dated February 7, 2012 and approved by USEPA on March 29, 2012. The Facility is depicted on Figure 3.

1.1 Objectives and Approach

The objectives of the groundwater modeling effort were to determine if site-related contaminants (including TCE) in groundwater beneath the Facility have 1) migrated off-site; and/or 2) become comingled with the upgradient sources of groundwater contamination identified within the OU-3 Study Area. These objectives are met by development of a Facility-specific transient groundwater flow model using the existing Central Phoenix Plume Model (CPM), coupled with solute transport simulations to evaluate potential contaminant transport. The CPM was selected because it was commissioned for ADEQ, and has also been deemed applicable (with recommended adjustments) for use in the Motorola 52nd Street Superfund Site by USEPA (USEPA, 2000).

The approach to this modeling evaluation included 1) refining the conceptual site model (CSM), based on the information in the USEPA-approved Sitewide FRI; 2) creating the smaller scale Facility-specific model from the CPM using telescopic grid refinement techniques; 3) calibrating the smaller scale model to reflect localized groundwater conditions; and 4) conducting contaminant transport simulations.

Constituents of Concern (COCs) for the Motorola 52nd Street Superfund Site (M52 COCs) were identified in the AOC and include the following:

- Tetrachloroethene (PCE);
- TCE;
- Vinyl Chloride (VC)/Chloroethene (CE);
- 1,4-Dioxane;
- Chloroethane (CA)/Ethyl Chloride (EC);
- 1,1-Dichloroethane (1,1-DCA);
- 1,2-Dichloroethane (1,2-DCA);
- 1,1-Dichloroethene (1,1-DCE);
- cis-1,2-Dichloroethene (cis-1,2-DCE);
- trans-1,2-Dichloroethene (trans-1,2-DCE);
- 1,1,1-Trichloroethane (1,1,1-TCA); and
- 1,1,2-Trichloroethane (1,1,2-TCA).

Both historical and Focused RI-related analytical testing conducted at the Facility included the M52 COCs outlined above, as well as a number of other constituents (non-M52 constituents). As the documentation (chain-of-custody documents and analytical data reports) contained both M52 COCs and non-M52 constituents, the tabulated data contains both data sets, although separated. The AOC-required M52 COCs are included and described in the text sections, tables and figures of this Groundwater Flow and Solute Transport Report and the results for non-M52 constituents are included and summarized in Appendix A.

1.2 Report Organization

To support these objectives, this report is organized as follows:

- Section 1.0 Introduction
- Section 2.0 Conceptual Site Model
- Section 3.0 Regional Groundwater Flow Model
- Section 4.0 Facility Groundwater Flow Model
- Section 5.0 Solute Transport Model
- Section 6.0 Uncertainties and Limitations
- Section 7.0 Summary of Modeling Activities and Conclusions
- Section 8.0 References

2. Conceptual Site Model

The following sections presents the CSM for the Facility. The majority of information for this portion of the report was obtained directly from the USEPA-approved FRI report and earlier reports prepared during the Focused RI and approved by USEPA. Although the Facility was investigated as a whole, it became apparent that as a result of the investigations, the Facility should be divided into portions, which would guide activities into the future (*e.g.*, the need for remediation and/or the potential to close portions of the Facility that were not sources of contamination) (ARCADIS, 2012). Therefore, the Facility was divided into the Northern Portion (AdobeAir Warehouse) and the Southern Portion (remainder of the Facility). Although the entire Facility is described herein, the CSM will generally focus on the Northern Portion of the Facility, as no environmental concerns were identified within the remainder of the facility (ARCADIS, 2012).

2.1 Facility Settings

The Facility is located at 500 South 15th Street, in Phoenix, Arizona 85034. It is situated within central Phoenix and is approximately one mile west of Phoenix Sky Harbor International Airport (Figures 1 and 2). The entire Facility, including the AdobeAir Warehouse is approximately 28 acres in size and is physically located within the southeast ¼ of Section 9, Township 1 North, Range 3 East of the Gila and Salt River Baseline and Meridian system, in Maricopa County, Arizona.

The Facility is bordered to the north by the Union Pacific Railroad (formerly Southern Pacific) switch yard and Walker Power Systems (formerly Tiernay Turbines), an aviation equipment manufacturer. To the east are 16th Street, the Salt River Project (SRP) 16th Street storage and maintenance facility, the City of Phoenix Sky Harbor Center, and vacant land. To the south, the Facility is bordered by Hadley Street; a parking lot (part of the Facility property); FMC, a former pesticide blending facility; and other commercial facilities. The Facility is bordered to the west by 14th Place, followed by an American Gypsum manufacturing facility (Figure 2).

In addition to the 500 South 15th Street address, the following addresses have also historically been used to identify Facility parcels:

- 1502 East Hadley Street
- 515 South 14th Place
- 535 South 14th Place
- 1430 East Hadley Street

Currently, the Facility consists of several buildings, formerly used for manufacturing, storage, administration and maintenance (Figure 3). Areas surrounding the buildings are generally paved with concrete, with minor landscaping near the administrative offices at the AdobeAir Warehouse, central employee parking, the southwestern perimeter of the property and the northwestern-most portion. Storm water is directed off the buildings into storm drain lines that extend generally north-south between the buildings, and drain either to drywells located in the central and western portions of the Facility or to the City of Phoenix sewer system. An exception to this is the AdobeAir Warehouse, where storm water is directed off the roof to a retention basin which extends along its northern side. This retention basin also accepts storm water from the cul-de-sac ending of 14th Place. Access to the Facility is provided from Grant Street, a driveway off of Hadley Street and along 14th Place to the west.

2.2 Facility Operational History

The Facility consists of buildings, formerly and currently used for industrial manufacturing, storage, administration, and maintenance. The property where the Facility is situated is zoned Heavy Industrial (A-2) by the City of Phoenix and was used for manufacturing of evaporative coolers and space heaters from approximately 1945 to 2003. The industrial processes conducted at the Facility included sheet metal stamping; welding; metal preparation and painting; powder finishing; and final assembly of coolers and heaters. Final products were packaged and warehoused on site awaiting final shipment. The following sections present a brief summary of the Facility operational history starting in 1945, excerpted from the Final Research Report (RR) (ARCADIS, 2005).

2.2.1 1945 – 1960

Adam D. Goettl owned the property from 1945 through 1960. He began manufacturing operations under the name of International Metal Products Company (IMP) around 1945. Ralston-Purina and others (including Arizona Citrus Growers) also had limited operations on portions of the Facility during the Goettl ownership period.

2.2.2 1960 – 1982

McGraw-Edison Company purchased portions of the Facility beginning in 1960. According to Cooper Industries, LLC's (successor to McGraw-Edison Company) records, a portion of the Facility, which included the manufacturing operations, were sold by IMP to McGraw-Edison in 1970. The manufacturing business was operated as IMP Division. By 1978, the entire Facility had been sold to McGraw-Edison.

During the 1960s and 1970s, IMP's evaporative cooler manufacturing processes included metal stamping, metal plating, painting and paint stripping operations as well as assembly of finished coolers. Two 1,000-gallon underground storage tanks (USTs) were installed in 1962 for paint thinner storage. Personnel indicated that used solvents and paint waste from dip-type stripping processes were apparently stored in large concrete tanks near the northwest corner of the manufacturing facility. However, it is not certain if the two sets of tanks described are a single storage system, or if virgin materials were stored in one tank and used solvents/paint wastes stored in the other.

2.2.3 1982 – 1991

In April 1982, Arvin Industries purchased the manufacturing business and Facility property from McGraw-Edison Company - IMP Division. A short time later Arvin Industries changed names to ArvinAir, Inc. continuing to make evaporative coolers. Also, turbines, space heaters, and fireplace heat exchangers were added to the production lines at the manufacturing facility.

ArvinAir, Inc. made additional changes to the manufacturing and waste treatment processes. The painting processes were changed in late 1982 to use a non-toxic powdered paint material. This change in process, along with burning the excess paint off of the hooks used to carry painted parts, eliminated the need for liquid paint strippers. The other solvent usages remained unchanged. In 1986, a major fire burned some of the buildings and almost all company records. The manufacturing facility was reconstructed and included a warehouse in the northwest corner of the 500 South 15th Street Facility, where the solvent tanks were located, along with other new buildings. In 1987 and 1988, ArvinAir, Inc. also removed and closed several USTs including the solvent tanks noted above, and fuel USTs. The City of Phoenix Fire Department observed some of the tanks being removed, and Arvin Air, Inc. provided notification to the ADEQ in 1988 that the tanks had been removed (ARCADIS, 2005).

2.2.4 1991 – 2003

AdobeAir purchased the manufacturing business from ArvinAir Inc. in January 1991, and subsequently purchased the land and manufacturing facility from ArvinAir, Inc. in April 1994. AdobeAir conducted fabrication/assembly, warehousing and shipping operations at the Facility. AdobeAir occupied the Facility until the end of 2003, when fabrication/assembly operations were moved to Adobe's facility in Monterrey, Nuevo Leon, Mexico.

2.2.5 2003 – Present

In 2003, the entire 500 South 15th Street property was sold to Phoenix Adobe Partners, LLC, (PAP), an Arizona limited liability company. Harrison Properties, LLC is the managing member of PAP. Buildings 5, 6, and 7 on the southwestern portion of the property and within the Southern Portion were demolished as part of a redevelopment effort. A new building to be used as a warehouse was completed at that location in the summer of 2005. Harrison Properties, LLC leased the northwestern warehouse building to AdobeAir, Inc. New tenants have leased the remainder of the facility since 2005. Figure 3 shows the current improvements and identifies tenants most recently in place within the on-site structures.

2.3 AdobeAir Warehouse Source Area Investigation Summary

This section describes historic investigation activities conducted within the AdobeAir Warehouse regarding the paint thinner USTs, beginning in 1989.

2.3.1 Two Concrete Storage Tanks

Scott, Allard & Bohannan (SA&B) reported that two old concrete storage tanks were apparently used by McGraw-Edison to store virgin mineral spirits (SA&B, 1989). At the time of the assessment, Arvin Air, Inc. personnel informed SA&B that the tanks had not been used since the mid 1970's. SA&B reported that the tanks had been abandoned, partially dismantled, and covered with concrete. Later it was learned that one of the tanks had been removed in 1988 during a geotechnical foundation assessment and the other had been abandoned in place. At the time of the 1988 geotechnical assessment a broken water line was discovered in the area of the old concrete storage tanks. Water leaking from this line had saturated soils in the area. Saturated soil was also reported during the tank abandonment and removal (ARCADIS, 2005). No information was given concerning the size or the dimension of the tanks with the exception that the tank depth was reported to be 4.5 feet (ft) below ground surface (bgs) (The ADEQ UST Report documented that the USTs were approximately 1,000-gallon tanks).

Two soil borings were reportedly advanced in the middle of the two concrete USTs (R1-1-2 and R1-1-3). A third boring, R1-1-1, was advanced approximately 20 ft southwest from the location of the tanks. R1-1-1 was thought to be upgradient from the potential contamination source and was meant to serve as a background sample. The boring locations are shown on Figure 4. Concrete was reported in R1-1-3 from 1.5 to 4.5 ft bgs. Concrete was not encountered, with the exception of the surficial concrete in both of the other two borings. Auger refusal was encountered at 10 ft bgs. Samples were collected at four and nine ft bgs from boring R1-1-1, at four and 10 ft bgs from boring R1-1-2, and at five ft bgs from boring R1-1-3.

Soil samples were analyzed for VOCs in accordance with USEPA Method 8010/8020 and for lead and chromium using a total metals analysis. 1,1,1-TCA was reported at concentrations ranging from not detectable at the laboratory reporting limit to 0.019 milligrams per kilogram (mg/kg). TCE was detected at 0.037 mg/kg, PCE was detected at 0.005 mg/kg, and 1,2-DCA was detected at 0.003 mg/kg in R1-1-2 at 10 ft bgs. A summary of the historic soil sample analytical results for M52 COC is presented in Table 1.

2.3.2 Soil Vapor Survey

In July 1993, SA&B contracted Tracer Research Corporation (TRC) of Tucson, Arizona to conduct a soil vapor survey to confirm the presence and location of the concrete tanks or structures at the northwest corner of the Facility beneath the former AdobeAir, Inc. warehouse (Figure 4). With little to unknown information about the structures, SA&B decided that a soil vapor survey would be the most effective way of locating a possible source for the impacted soil identified during the 1989 soils investigation, and of elevated groundwater concentrations in groundwater monitoring well MW-4 stated in the groundwater monitoring report (see Section 2.5).

A total of fifteen soil vapor samples were collected from twelve soil vapor locations (Figure 4). After coring through the concrete floor, a ¾-inch diameter steel pipe with a detachable aluminum drive point was driven into the subsurface. A second concrete pad was encountered at approximately two ft bgs (below ground surface), also approximately six inches thick. SA&B speculated that the lower concrete pad was the floor of a previous building. Although SA&B did not indicate the soil type between the two floors in their report, building plans reviewed by ARCADIS indicate that the material was aggregate base course (ABC). The drive points for collecting the soil vapor samples were driven to depths ranging from seven to 10 ft bgs. The drive point was stopped due to refusal from the presence of coarse grained soils below. At three sample locations, soil vapor samples were collected at two ft bgs (between the concrete pads) and again at approximately 10 ft bgs. The samples collected at two ft bgs samples were collected for comparison with the deeper soil vapor samples. All samples were analyzed by an on-site analytical laboratory for 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE, PCE, and TCE. The soil vapor samples were collected in a manner consistent with industry standards at the time of the investigation.

TCE had the highest detected concentration of the VOCs analyzed, and was reported to be present at concentrations ranging from 0.04 milligrams per cubic meter (mg/m^3) in SG-10-2’ to 11,000 mg/m^3 in sample SG-3-9’. The highest detected TCE concentrations were identified in soil vapor samples SG-1-10’, SG-3-9’, and SG-4-9.5’ at concentrations of 3,400 mg/m^3, 11,000 mg/m^3, and 1,000 mg/m^3, respectively. In addition, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE, and PCE were all detected at sample locations SG-1, SG-2, SG-3, and SG-4. The soil vapor analytical results for M52 COC are presented in Table 2.

2.3.3 Soil Contamination Source Removal

SA&B conducted a program of excavation and disposal in the northwestern portion of the AdobeAir Warehouse in an attempt to remove the apparent source of chlorinated solvent contamination in soil, soil vapor and groundwater identified during previous investigations during the period from 1989 to 1993. The excavation work began in

September 1994 and was completed in November 1994. In accordance with an ADEQ-approved Workplan, SA&B initiated a three stage process to conduct the removal action including 1) excavation around and between the building foundations to determine the location of the concrete structures; 2) excavating an area 10-ft by 12-ft in size near soil vapor sample location SG-3; and 3) providing structural support to the warehouse prior to removing contaminated soil. However, prior to implementing construction activities, additional information found regarding the concrete structures resulted in an ADEQ-approved reduction of the Stage 1 tasks to collecting three soil samples outside of the northern border of the warehouse. The soil samples were collected using a soil auger and were labeled SS1, SS2, and SS3 (Figure 4). Samples were collected at 8.3, 7.3, and 8.3 ft bgs, respectively. Sample analytical data is tabulated in Table 1.

Stage 2 involved excavating a portion of the warehouse floor. Concrete structures, pipes, and some of the surrounding soils were removed from the excavation and placed in roll-off bins pending testing and analysis. Several subsurface soil samples and one liquid sample were collected during the excavation activities. Soil samples were analyzed for halogenated VOCs in accordance with USEPA Method 8010.

A concrete structure was identified at the location of soil vapor survey sample SG-3. This structure was described as consisting of an enclosed concrete box filled with soil. The only opening was a hole at the top. Sample ARV-ICS-BP-21 was collected from within the structure and sample ARV-UCS-9 was collected from under the concrete structure at an approximate depth of 10.7 ft bgs.

Two other concrete structures were also discovered in the excavation. The first was a concrete sump, which was found east of the original concrete structures. The sump appeared to be connected to a sewer line that drained from the south. In addition, a second pipeline from the sump connected with the original concrete structure, indicating that the structure also drained into the sump.

A third pipeline was found which extended to the north. Attempts to trace this third pipeline failed, but the pipeline was reported to “extend only 1 to 2 ft beyond the concrete sump to the north (SA&B, 1995)”. The sump was removed; however the pipeline from the sanitary sewer was left in place.

The other concrete structure found was south of the original concrete structure. This structure had been backfilled with soil. SA&B reported that company records and plans referred to this structure as a “solution vessel”. Copies of these historical records were not provided in the report. No liquids or evidence of liquids were observed in or near this structure. A portion of the vessel was uncovered during the investigation, but had no pipelines connected to it. A portion of the vessel extended beyond the excavation area and additional excavation could not be completed because extending the excavation further would have required relocation of warehouse equipment and structural building support would have been necessary.

During the excavation, most of the soil and debris was removed to depths ranging from five to 10 ft bgs. Cemented sands, gravel, and cobbles were encountered which prevented further excavation. The excavated area was approximately 384 square ft in size. These dimensions result in an approximate range of 1,920 cubic ft to 3,840 cubic ft or 71 cubic yards to 142 cubic yards of material excavated. The obviously impacted soils and the concrete structure were placed in roll-off bins and disposed of as characteristic hazardous wastes. The less contaminated soils and most of the exposed appurtenances were placed in roll-off bins and disposed of as non-hazardous wastes. A portion of the pipeline and the solution vessel were left in place due to concerns with structural integrity of the building.

Several soil samples were collected beneath the vessel. The analytical results for M52 COC are reported in Table 1. Soil concentration results for PCE and TCE exceed the current Arizona Residential Soil Remediation Levels (SRLs), 1,1,1-TCA exceeded the current Arizona Groundwater Protection Level (GPL), PCE exceeded the current USEPA Industrial Regional Screening Level (RSL), and TCE exceeded the current USEPA Residential RSL. The leachable concentration of TCE in soil was determined by the toxicity characteristic leachate procedure (TCLP) extraction method and analysis for VOCs to be 1.10 milligrams per liter (mg/L) at 6.5 ft bgs. The TCLP concentration exceeded the current Arizona GPL for TCE of 0.61 mg/Kg.

2.3.4 VLEACH Model

At the request of ADEQ, following the source removal activities, a simulation of VOC movement in the vadose zone was performed using the VLEACH model (SA&B, 1995). This model was developed as a one-dimensional finite difference model for simulating vertical mobilization of dissolved organic compounds through the vadose zone and to predict groundwater impacts.

The VLEACH model incorporates the following considerations:

- Homogeneous soil properties.

- Depth dependent initial VOC soil concentrations.
- Constant source release rate.

The VLEACH model calculates steady state flow and transport associated with the leaching of VOCs to groundwater, sorption of dissolved VOCs, and volatilization and diffusion of VOCs.

Property-specific VOC concentrations along with published soil parameters and regional groundwater data were input into the model. A series of polygonal shapes were used to represent the impacted soil area (Figure 5). Each of the areas was assigned the maximum observed concentration of TCE based on investigation results. In addition, the same concentration was assumed for the entire soil column. The VLEACH model was then used, with various input parameters, to estimate the mass of TCE that would be expected to migrate to groundwater over time.

The VLEACH simulation was performed first for a time interval of 2,000 years. Results of this simulation indicated that the majority of mass loading to groundwater occurs within the first 100 years. The simulation was then conducted over a period of 100 years. The highest impact to groundwater was found to occur within the first year.

A single cell groundwater mixing model was used to convert mass loading to equivalent groundwater concentrations. TCE groundwater concentrations for the VLEACH simulation period of 100 years were calculated. The model predicts a TCE concentration of 115.4 micrograms per liter (µg/L) in the first year, decreasing to 90.3 µg/L in year 100. These values are somewhat higher than concentrations observed in groundwater beneath the Facility which varied from a high of 59 µg/L in 1992, to 12 µg/L in 1994, following the soil removal program.

The VLEACH model, as run by SA&B, generally provides a conservatively high estimate of VOC impacts to groundwater. The following characteristics of the model contribute to the conservative results the model provides:

- Retardation of VOC movement to soil mineral sorption is not considered.
- Reduction of VOC concentrations due to biological or chemical degradation is not considered.
- Dispersion and volatilization of VOCs at the vertical vadose zone boundary is not considered.
- VOC transport time to groundwater is instantaneous since it was assumed that the entire soil column had been impacted.

- Conservative input values.

The results of the VLEACH simulation are biased to simulate higher concentration loadings to groundwater, due to the fact that the highest concentration identified was determined to be present in all the areas and all the depths at this portion of the Facility, which is not typical of the Facility. Additionally, a source removal activity was conducted, and significant amounts of contaminated soil were removed; however, this fact is not reflected in the VLEACH model. Therefore, the VLEACH simulation is overly conservative and not reflective of actual conditions at the Facility. The model results were presented to the ADEQ, who generally agreed with the limitations of VLEACH, and its potential to overstate potential contamination in groundwater.

2.3.5 Two Former Gasoline USTs

Two USTs were removed in August 1988. The tanks were reportedly used to store gasoline and were located near the Facility's West Gate entrance off of 14th Place (see Figure 3 for the West Gate location). The tanks were removed in compliance with the City of Phoenix Fire Department procedures and no problems or environmental concerns were noted at the time of their removal. No information was provided regarding the tank capacity or orientation in the report. However, a review of the ADEQ database indicated that the tank capacities were 500 gallons each.

There was no information provided regarding any piping or dispensers associated with the USTs. In addition, SA&B could not find any information describing tank pit depth. Therefore, SA&B assumed the base of the tanks were somewhere between 8 and 12 ft bgs. Other documents studied as part of the RR (ARCADIS, 2005) indicate that the USTs were approximately 500 and 1,000 gallons. Three soil borings were advanced in what was reported as the vicinity of the former tank pit, although the boundaries of the former tank pit location were not shown on the diagrams. Soil boring R3-1-1 was advanced to 11.5 ft bgs. R3-1-2 was advanced to 7 ft bgs. Soil boring R3-1-3 was advanced to 9 ft bgs. Samples were obtained at depths of four ft bgs and an attempt made at the bottom of each boring. Only the sample collected at R3-1-1 was submitted for laboratory analysis.

The R3-1-1 sample was analyzed for VOCs in accordance with USEPA Method 8010/8020 for VOCs and fuel constituents and for fuel and petroleum hydrocarbons in accordance with Arizona Department of Health Services (ADHS) Modified method 8015 and USEPA Method 418.1, respectively. No solvents were detected in the sample. A summary of the historic soil sample analytical results for M52 COCs is presented in Table 1.

2.3.6 Northern Portion of the Facility Focused RI-Related Investigation

Initial soil sampling conducted between 1989 and 1994 in the Northern Portion of the Facility indicated that a number of potential contaminants were present in soils. PCE concentrations exceeded the ADEQ residential SRL and the USEPA industrial RSL. TCE soil concentrations exceeded the current ADEQ residential SRL and USEPA residential RSL. 1,1,1-TCA soil concentrations exceeded the current GPL. M52 COC were detected above the screening levels in some soil samples beneath the former AdobeAir Warehouse.

Soil vapor investigation in the Northern Portion of the Facility was conducted near drywells, and near the former solvent and fuel USTs. A total of 72 locations were investigated at depths ranging from nine to 15.2 ft bgs. Analytical results indicated that 1,1,1-TCA, 1,1,2-TCA, 1,1-DCA, 1,2-DCA, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, PCE, and TCE were detected.

The soil vapor results were compared to calculated soil vapor screening levels for residential and industrial use scenarios using the November 2011 (February 2012 IRIS values for PCE) USEPA indoor air RSL divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (greater than five ft below ground surface). The rationale for using these calculated screening levels with the deep soil vapor attenuation factor versus the default Soil Gas Human Health Screening Levels (SGHHSLs) which use the shallow soil vapor attenuation factor of 0.0023 was to provide a robust, conservative risk evaluation for soil vapor beneath the Facility. The derived soil vapor screening levels were identified as calculated soil vapor screening levels (C-SVSLs) to differentiate them from indoor air RSLs. For the Focused RI-related soil vapor investigation, 1,1,2-TCA, 1,1-DCA, 1,2-DCA, PCE and TCE were reported to exceed the C-SVSLs for either residential or both residential and industrial uses. Soil vapor analytical data for M52 COC are tabulated in Table 2.

In order to evaluate the vertical extent of COCs reported in the soil vapor beneath the AdobeAir Warehouse and address potential for migration of contaminants to groundwater, vapor monitoring well VMW-01 (a four zone nested vapor well) was installed in 2007. The sampling depths for VMW-01 were designated VMW-01[12.5], [40], [55], and [79.5], which is equivalent to the top of the screened interval for each portion of the nested well. Detected M52 COC in the nested vapor well include 1,1,1-

TCA, 1,1,2-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,4-Dioxane, cis-1,2-DCE, PCE, TCE, and trans-1,2-DCE. Concentrations have not demonstrated any specific trends with depth at vapor monitoring well VMW-01.

2.4 Soil Vapor Extraction Program

A soil vapor extraction (SVE) program, including conducting a pilot test and construction of a full scale remedial system has been implemented at the Facility to address VOCs in soil vapor. The SVE program began with a pilot test, conducted in the northwest portion of the Facility, within and adjacent to the AdobeAir Warehouse Building in September 2008 (ARCADIS, 2009). The purpose of the SVE pilot test was to evaluate the effectiveness of the technology to create a treatment for vadose zone soils beneath the AdobeAir Warehouse Building containing VOCs. The SVE pilot test had the following primary objectives:

- Obtain a pneumatic conductivity estimate for vadose zone soils.
- Evaluate contaminant loading and off-gas treatment.

In preparation for the pilot test, the following vapor monitoring well network was created for data collection:

- The installation of two new multi-nested vapor monitoring wells (VMW-02 and VMW-03) to a total depth of 85 ft bgs and 81 ft bgs, respectively;
- Retrofitting one existing groundwater monitoring well into a dual groundwater (MW-4) and nested vapor monitoring well (VMW-04 [50] and VMW-04 [75]);
- The installation of an additional shallow single-port vapor monitoring well, VMW-04 (13), adjacent to MW-4, VMW-04 (50) and VMW-04 (75).

Based on the data obtained during the pilot test, a full scale SVE system was designed and the design approved by USEPA in 2010. The system was constructed and began full operation in June 2011 (Figure 4).

The full-scale SVE system consists of two SVE wells (SVE-01 and SVE-02), each screened across four independent intervals, a manifold that interconnects the network of SVE well conveyance piping, a sump network, an air/water separator and a vacuum blower. SVE-01 was installed inside the Site warehouse building and SVE-02 was installed west of the warehouse building in the northwest corner of the Site. The SVE well locations were selected based on the nature and extent of soil gas impacts at various depths, the results from the SVE pilot study test and expected optimal source removal rates. Each SVE well consists of four independent extraction intervals, ten ft in length, and screened from approximately 10-20 ft bgs, 30-40 ft bgs, 50-60 ft bgs, and 70-80 ft bgs, respectively. Underground conveyance piping connects the SVE wells to the to the SVE sump network and treatment system enclosure. The piping for each well exits the sump and enters a manifold to interconnect the conveyance pipes into one that feeds a common vapor stream to the SVE system. Any entrained liquid water or water vapor condensate not captured by the sump network is controlled and removed by a cyclonic moisture separator. The extraction system is operated using a 20 HP ROTRON™ regenerative vacuum blower, capable of operating at flow range rate of 350 to 1,000 standard cubic feet per minute (SCFM) and a maximum vacuum level of 70 inches of water. The blower was selected to provide two pore volume exchanges per day, based on calculations using an assumed soil porosity of 25%, a vadose zone thickness of 88 ft and a desired radius of influence of 80 ft (or approximately 615 SCFM).

SVE Operation, Maintenance and Monitoring (OM&M) and SVE System influent and effluent sampling have been conducted as part of on-going monthly activities for the SVE System since start-up in June 2011. The following summarizes results obtained as of the July 2012 reporting period, when the system was shut down for a rebound test:

- The SVE System operated in excess of one year with a cumulative up-time percentage of 90 percent. The contaminant mass removal rate has stabilized since January 2012 and has become asymptotic at a daily removal rate near 0.01 pounds of VOCs per day. The total mass of VOCs removed since June 2011 is approximately 10.2 pounds. The original in-place mass estimate, based on the historical maximum soil vapor concentration of the eight most significant detected VOCs was approximately 5.4 pounds. The SVE System has extracted nearly twice this amount because several non-M52nd Street constituents contribute to the total mass of VOCs removed.

- The SVE System has removed all readily extractable VOC mass in the vadose zone. However, VOC mass may still be present in sequestered pore spaces and in pore water, but is not available to mobile soil vapor during extraction operations because the air extraction rate may exceed the diffusive mass transfer rate from sequestered pore space and pore water to the mobile air space. ARCADIS is evaluating whether VOC mass is still present in the vadose zone in a sufficient quantity to generate soil vapor concentrations exceeding C-SVSLs by temporarily deactivating the SVE System. The SVE System was deactivated on July 27, 2012 following sample collection to initiate the rebound test.

2.5 Facility Groundwater Quality

Groundwater monitoring wells were installed at the Facility in 1991. Monitoring and sampling was conducted during 1992, then sporadically between 1992 and 2005, and semi-annually since 2006 to determine the presence and concentration of COC in groundwater within Facility monitor wells (ARCADIS, 2012). The groundwater monitoring program included monitoring and sampling of six wells (MW-1 through MW-6, located across the entire Facility) between 1992 and 2005, the abandonment of monitor wells MW-1, MW-2, MW-3, MW-5, and MW-6 between 2005 and 2007, and the installation of groundwater monitor wells, MW-7, MW-8 and MW-9 in 2008. Only MW-4 and MW-7 are located in the Northern Portion of the Facility.

Groundwater samples collected in 1992 had detectable concentrations of 1,1,1-TCA, 1,1-DCA, 1,1-DCE, PCE, and TCE. MW-1 (most upgradient well on-site) had detected concentrations of each of the constituents outlined above during 1992. In general, more of the M52 COC were detected in the upgradient wells than those downgradient, although the concentrations are similar from upgradient to downgradient with the exception of MW-4. The concentration of TCE in monitor well MW-4 exceeded the current Arizona Aquifer Water Quality Standard (AWQS) and USEPA Maximum Contaminant Level (MCL) of 5 µg/L. The highest concentration of TCE reported in MW-4 was 59 µg/L in July 1992. The samples collected in 1994 from monitor wells MW-1, MW-2, and MW-3 did not contain COC at or above method reporting limits. However, MW-4 had detectable concentrations of 1,1-DCE (0.2 µg/L), cis-1,2-DCE (0.2 µg/L), and TCE (12 µg/L). This concentration of TCE exceeds the current MCL and AWQS. The samples collected in 1999 also did not contain COC at or above method reporting limits, with the exception of MW-4 with a TCE concentration exceeding the MCL and AWQS.

Since initiation of the semi-annual groundwater sampling in 2006, M52 COC which have been detected above method reporting limits in groundwater samples (ARCADIS, 2006a, 2006b, 2007a, 2007b, 2008, 2009a, 2009b, 2009c, 2011a, and 2011b) include 1,1-DCA, 1,4-Dioxane, 1,2-DCE, PCE, and TCE. A summary of the analytical results for the M52 COCs in groundwater are presented in Table 3. Groundwater flow direction and gradient as of March 2011 are depicted on Figure 6. As of March 2011 (last data reports approved by USEPA as of the time of this report), in the monitor wells associated with the Northern Portion of the Facility, TCE concentrations were below the current MCL and AWQS standards of 5 µg/L in both monitor wells MW-4 and MW-7.

Hydrographs and concentration curves for TCE were created for each monitor well MW-1 through MW-9 and are presented in Appendix B. TCE concentration, when detected above the method reporting limit, generally follows a similar trend as groundwater elevations in monitor wells associated with the Northern Portion of the Facility. Monitor well MW-7, which is located near monitor well MW-4, but is screened at a higher elevation, shows increasing TCE concentrations as groundwater elevations continued to rise between 2008 and 2011. The stronger correlation in MW-7 versus MW-4 may be due to monitor well MW-7 being screened across a greater interval. This trend in monitor well MW-7 may indicate that the vertical differentiation in TCE groundwater concentrations is occurring as groundwater flows across TCE-impacted soils which may mobilize contaminants out of the pore spaces.

2.6 Geology and Hydrogeology

Geologic and hydrogeologic conditions associated with the project area, correlations with local Phoenix area groundwater conditions, and to specific conditions beneath the Facility are described in this section.

2.6.1 Regional Geology and Hydrogeology

The Phoenix area is part of the Salt River Valley Basin (SRVB) within the Basin and Range physiographic province. The SRVB lies within a broad alluvial valley composed of Cenozoic age sedimentary deposits surrounded by generally northwest/southeast trending mountain ranges.

The sedimentary deposits comprising the basin are underlain by sedimentary, crystalline and volcanic bedrock formations that vary in age from early Tertiary to Proterozoic. These rocks are typically metamorphosed to various extent. These basement rocks can be seen outcropping at a variety of locations throughout the Salt River Valley, including the Phoenix Mountains, South Mountain, Papago Buttes, Tempe Buttes and Camelback Mountain.

The older basement rocks consist of Pre Cambrian age meta-volcanics and granites. These rocks are typically overlain unconformably by mid-Tertiary age basement sediments and volcanics. The two types of basement rocks are in many areas structurally altered due to tectonic stresses coincident with the Basin and Range physiographic features.

The hard basement rocks generally exhibit relatively lower hydraulic conductivity and porosity characteristics than the overlying valley fill sediments and typically form a groundwater flow boundary. The bedrock units may locally contain and transmit small quantities of groundwater where fractured, but is not regarded as an aquifer on a regional scale.

The overlying sediments in the SRVB consist of unconsolidated to semi-consolidated alluvial deposits of late Tertiary to Quaternary age. These units vary in thickness from less than 100 ft to as great as 10,000 ft, and consist of interbedded sequences of sands, gravels, silts, clays and evaporites. Generally the clastic facies become finer-grained toward the central basin areas.

Stratigraphic descriptions for the basin fill deposits vary somewhat by author, but generally incorporate a coarse upper part, a relatively fine middle part, and a coarse, more consolidated lower part. All three parts may contain volcanics and occur in various extent and thickness correlating to their depositional environments. The three basic basin fill units form the principal aquifers for Phoenix and the surrounding areas.

One of the most accepted stratigraphic nomenclatures for the Salt River Valley fill is provided by the Arizona Department of Water Resources (ADWR) (ADWR, 1993), with a similar classification presented by the United States Geological Survey (USGS) (Brown and Pool, 1989). Previous investigations in the area, including development of the OU-3 Work Plan (IT, 2001), adopted the ADWR/USGS nomenclature in their lithologic descriptions.

The descriptions in Reynolds and Bartlett (2002) are “depositional facies” based, and may provide a more meaningful and detailed way of describing subsurface conditions in and around the Facility than the more general ADWR/USGS designations.

Both classification systems are similar. The Reynolds and Bartlett system provides greater detail for the greater project area, and is more useful for assessing hydrogeological and associated VOC transport conditions. Both basin fill classifications are summarized herein. The basin-wide area classification is discussed in this regional hydrogeology summary, and the Reynolds and Bartlett nomenclature is discussed in the following local hydrogeology section.

Based on the basin wide classifications of ADEQ (1993) and Brown and Pool (1989), the SRVB basin-fill material is divided into the following four stratigraphic units (from oldest to youngest):

- The Red Unit consists of reddish, poorly sorted, well-cemented breccia, conglomerate, sandstone and siltstone. This was largely deposited by debris flows; however there are inter-fingered volcanic deposits within the debris flows. These sediments were mostly derived from granitic and rhyolitic sources. Bedding is generally poorly defined except within the inter-fingering finer-grained units. The Red Unit reaches a maximum thickness of 2,000 ft.
- The Lower Alluvial Unit (LAU) overlies the Red Unit. There are two general subdivisions of the LAU. The lower portion consists of semi-consolidated homogenous and massive evaporite deposits of anhydrite and gypsum that were deposited in a closed basin. The deposits contain occasional inter-fingering of sand, gravel, and basaltic flows. The upper portion of the LAU is poorly sorted, weakly to moderately cemented siltstone, mudstone, gypsiferous mudstone, sand, and gravel.
- The Middle Alluvial Unit (MAU) ranges from zero to 800 ft thick from the east to the west, respectively. The MAU consists of consolidated interbedded clay, siltstone, silty sand, and gravel. These constituents were deposited in playa, alluvial fan, and fluvial environments. Grain size generally increases at shallower depths in the MAU.
- The Upper Alluvial Unit (UAU) ranges from 200 ft to 450 ft thick from the east to the west, respectively. The UAU consists of unconsolidated silt, sand, and gravel with some areas of calcium carbonate cementation. These constituents were deposited in flood plain, terrace, and alluvial fan environments.

The present groundwater flow system in the SRVB is relatively complex, because of various influences. Areas exist where the UAU has been substantially dewatered, and current flow gradients are much different than historic gradients. Generally, groundwater in the Salt River Basin flows to the west, from areas of higher topography to areas with less elevation associated with the Gila River to the west.

The SRVB consists of two interconnected alluvial groundwater sub-basins (ADWR, 1993): an eastern and western basin, which is generally equivalent to the East Salt River Valley (ESRV) and West Salt River Valley (WSRV). The ESRV Sub-Basin includes the eastern portion of the SRVB and the northern part of the Maricopa Stanfield sub-basin in Pinal County. The WSRV includes the western portion of the

SRVB, and northern portions of the Gila River Basin. The two basins are connected overall with regional flow to the west, yet a minor divide occurs between South Mountain, Tempe Buttes, Papago Buttes and the Phoenix Mountains.

In the western basin near the Facility, local subsurface characteristics influence groundwater flow. This specific area is discussed in greater detail in the following section.

2.6.2 Local Geology and Hydrogeology

As discussed in the previous section, the SRVB has been characterized to a great extent, although the exact depth and nature of the hard bedrock has only been characterized in detail in selected areas. One of these areas is the eastern Phoenix area north and northeast of the Facility.

As with the greater WSRV, the hard basement rock in the Motorola 52nd Street Superfund Site area is comprised of portions of the Red Beds, or mid-Tertiary age volcanics and sediments. These relatively less permeable units underlie the basin fill sediments. Many previous subsurface boreholes extend to bedrock in the area north and northeast of the Facility.

Exact basement geological delineations are not known in the Facility area because of a relative lack of detailed data. Basement rock elevation contours are extended through the Property area based on review of available lithologic data from ADWR and other sources as referenced.

The three main mid-Tertiary age rock units comprising the hard basement in the area are the Camels Head Formation, the Tempe Formation and unnamed volcanic rocks. During deposition of these mid-Tertiary age rocks, southern Arizona was experiencing crustal extension characteristic of the Basin and Range structural style. This resulted in a series of detachment faults being formed in the area surrounding South Mountain and other Phoenix area mountain ranges.

Basement rocks associated with the detachment faulting were broken into a series of tilted fault blocks. As reported by Reynolds and Bartlett (2002), the hard bedrock units in the study area are currently dissected by a number of normal faults, which have structurally displaced the originally near horizontal units into their present orientation of dipping 15 to 50 degrees to the southwest.

It is anticipated that the series of faults that dissect the basement rocks to the northeast of the Facility continues through the Facility area in accordance with the metamorphic core complex conceptual model for the area. The exact number of bedrock faults, as well as their exact orientation, are not specifically characterized beneath the Facility, but are thought to occur in a similar style as to the north (Reynolds and Bartlett, 2002).

The erosion of the bedrock pediment surface before deposition of basin fill sediments resulted in a surface with bedrock highs, or ridges, occurring in the area. Papago Buttes is one example of an exposed ridge. The bedrock ridges are typically composed of the relatively harder Camels Head Formation, which is more resistant to erosion.

One buried bedrock ridge has been delineated in the area southwest of Papago Buttes. This ridge has been studied extensively. It is 8,000 to 10,000 ft long, extending from Sky Harbor Airport north to about the intersection of 24th Street and Roosevelt Street. This ridge is typically 1,000 to 2,000 ft wide and reaches elevations of 1,050 to 1,060 ft above mean sea level (amsl). This elevation is about 50 to 60 ft below land surface. Shallow saddles occur along the ridge, which are about 30 to 40 ft lower than the highest ridge areas.

Evidence also exists for another buried ridge located approximately one mile west of the ridge described above. This ridge, to the extent it has been characterized, is somewhat smaller than the one to the east, extending in a northwest direction for at least 1,000 ft. This second buried ridge has a maximum elevation on the order of 920 ft amsl, which is about 150 ft bgs.

Overlaying the hard basement rocks in the Phoenix Area are basin fill sediments of late-Tertiary and Quaternary age. Investigations performed by Reynolds and Bartlett (2002) provide a more detailed description of basin stratigraphy in the Phoenix Area northeast, north and northwest of the Facility than previous, basin-wide nomenclature systems. Their nomenclature fits within the previously established delineations representative of the greater SRVB.

With respect to the basin wide basin fill stratigraphic nomenclature, the OU-3 Work Plan (IT, 2001), and subsequent reports indicated that the Facility, as well as the greater OU-3 area, is underlain by the UAU, and perhaps portions of the MAU. These deposits are represented using the Reynolds and Bartlett nomenclature as the Uppermost Alluvium, Salt River Gravels, and parts of the Basin Fill Unit. Based on the above referenced interpretations, little or no sediments representing the LAU are present in the greater project area.

The three general alluvial facies of the basin fill in the Phoenix Area increase in thickness from zero ft near Papago Buttes to hundreds of ft along the western portion of the study area. The bedrock ridges discussed above, result in local thinning in areas over the ridges. The basin fill facies are generally less consolidated than the bedrock units, but significantly more consolidated than the overlying Salt River Gravels.

Facies of basin fill consist of a basal unit derived from local pediment materials, a sandy facies representing distances farther from the material source, and a fine-grained facies further distant from the source. The fine-grained facies appears to occur in the area of the bedrock ridge discussed above (Reynolds and Bartlett, 2002).

Coarse Salt River Gravels overlie the Basin Fill alluvial deposits in the study area. They occur as a wedge that thickens to the west and southwest. These deposits are characteristic of channel deposits associated with the historic Salt River.

The uppermost alluvium forms the youngest deposit in the area and consists of a relatively thin layer of finer-grained silts, clays, sands with some gravel. These deposits likely represent flood plain or eolian depositional environments.

In terms of local hydrogeology, three main units exist in the local Phoenix Area (Reynolds and Bartlett, 2002):

- Hard Bedrock: Comprised of the Proterozoic and mid Tertiary age rocks which contain little groundwater. Because of relativity low hydraulic conductivity (K) characteristics (less than 0.01 to 0.3 feet per day [ft/day]), bedrock forms a natural lower barrier to flow with the over lying alluvial units. Numerous faults dissect these rocks, but apparently do not influence groundwater flow because they are relatively deep to be of significance in the local study area.
- Basin Fill: Comprised of the four depositional facies. Values for K vary with grain size. Values may vary from one to 60 ft/day.
- Salt River Gravels: Most of this deposit is saturated in the study area, making it an important aquifer. Hydraulic conductivity values range from 200 to 450 ft/day.
- Four hydrostratigraphic zones are now delineated within OU-3 study area, which are comprised of the Salt River Gravels and Basin Fill (Shaw, 2005).

- Shallow Zone: Within the Salt River Gravels; extends from the top of the water table (about 80 ft bgs) to approximately 100 to 115 ft bgs.
- First Intermediate Zone: Within the Salt River Gravels; about 55 to 85 ft thick with a base occurring at a depth of about 170 to 190 ft bgs; marked at the interval's bottom by a fairly continuous silt/clay layer about five to 15 ft thick.
- Second Intermediate Zone: Within the Salt River Gravels; about 30 ft thick with a base at about 200 to 225 ft bgs.
- Deep Zone: Within Basin Fill; consists of a massive clay unit; depth interval of approximately 230 to 270 ft bgs.

Groundwater flow in the alluvial aquifer within the OU-3 Study Area occurs in a generally west slightly southwest direction, as reported for the March 2011 sampling (ERM, 2012a). This direction is generally consistent with previous data.

The top of the saturated interval within OU-3 study area is between 78 to 90 ft bgs (ERM, 2012a). The alluvial aquifer is about 160 ft thick in the OU-3 study area. Groundwater gradients are reported to be on the order of 0.003 to 0.005 feet per foot (ft/ft) (WESTON, 2000). ERM conducted a series of aquifer tests in late 2011 within OU-3. A total of nine rising head (slug) tests were conducted in the Upper Salt River Gravels (from the top of the water table (about 80 ft bgs) to approximately 125 ft bgs) at various locations within OU-3. A series of stepped rate tests followed by a constant rate aquifer pumping test were also completed in the west central portion of OU-3 as part of this aquifer testing program (ERM, 2012b). Values for K from the slug test data ranged from 24 ft/day to 1,000 ft/day in the Upper Salt River Gravels with an average K of 188 ft/day. The constant rate testing resulted in K values ranging from 304 ft/day to 1,042 ft/day with the average being 624 ft/day. Previous studies indicated K values ranging from 5.6 to 450 ft/day (Conestoga-Rovers & Associates, 1997).

Groundwater flow in the Phoenix area is strongly influenced by the geometry of the alluvial units and the nature and orientation of the hard basement rocks. The top of the hard bedrock decreases in elevation from east to west, creating a western deepening basin comprised of alluvium. The bottom of this basin contains northwest trending bedrock ridges as discussed earlier.

The ridge located north of Sky Harbor Airport has been studied extensively. This feature was exposed during late-Tertiary time, resulting in no basin fill deposits over the ridge. The 50 to 60 ft of Salt River Gravels overlie the ridge to near ground surface. Due to its configuration and relatively low permeability, this ridge forms a barrier to southwestern groundwater flow and associated VOC transport. In 2001, groundwater flow was reported to have been diverted around the north and south ends of the ridge, and through a southern saddle (Reynolds and Bartlett, 2002).

The second bedrock ridge to the west of the ridge north of Phoenix Sky Harbor International Airport is similar in dimensions, but is deeper because of the sloping of the bedrock surface to the west. This feature has not been studied to the same degree, and it is not currently known how much this feature affects groundwater flow. This crest of this ridge occurs about 140 ft lower than the ridge north of Phoenix Sky Harbor International Airport, or about 150 to 200 ft bgs. Because depths to groundwater in the area are on the order of 80-90 ft bgs, this second ridge is likely not a barrier to shallower groundwater flow.

Migration of VOCs in the groundwater in the Phoenix area is influenced primarily by the following hydrogeological controls:

- Geometry and hydraulic conductivities of basin alluvial deposits, which form the usable aquifer in the area.
- The irregular nature of the boundary of the alluvial deposits and underlying relatively tight bedrock deposits.

2.6.3 Facility Hydrogeology

The Facility is located near the southern edge of the Motorola 52nd Street OU-3 Study Area, but is separate from the identified groundwater plume (Figure 7). Much of the hydrogeological characteristics discussed in the previous section can be interpolated for this specific area. In addition, a substantial amount of subsurface exploration has been performed at the Facility.

Numerous investigations conducted previously (SA&B, 1992a, 1992b, 1992c, and 1993) provide hydrogeologic characterization information specific to the Facility. These data can be used with the substantial amount of information that exists to the northeast, north and northwest to derive an understanding of the hydrogeological conditions beneath the Facility.

The subsurface at the Facility including the Northern Portion is characterized from the surface to seven to ten ft bgs as generally consisting of fine grained materials. These materials consist primarily of sandy clay to clayey and silty sand, and fine poorly graded sand. Below seven to ten ft bgs generally the soils change to well graded gravel and cobbles with sand that extend to groundwater, which was identified to be approximately 70 ft bgs and is recently (as of March 2011) at a depth of approximately 81 ft bgs (SA&B, 1989, and ARCADIS, 2011c). Figure 8 provides the location of two Facility-specific geologic cross- sections and Figure 9 presents the geologic information.

Monitoring of groundwater monitor wells installed at the Facility indicate that the direction of groundwater flow is west-northwest, with a hydraulic gradient of 0.0019 ft/ft ARCADIS, 2011c). This flow direction and gradient has been reported to be generally similar between 1991 and the present. Groundwater velocities generally range from 5.6 to 450 ft/day in the OU-2 and OU-3 areas (Conestoga-Rovers & Associates, 1997).

3. Regional Groundwater Flow Model

The CPM was developed between 1997 and 2000 for the ADEQ by Roy F. Weston, Inc. (WESTON, 2000). The CPM was commissioned by ADEQ to provide a comprehensive understanding of groundwater flow in central Phoenix, and was developed based on four previous groundwater models within the Phoenix area:

- The Motorola 52nd Street Facility model (Motorola, 1995)
- The ADWR/ADEQ Central Phoenix Target model (Corell, 1992)
- The ADWR Salt River Valley (SRV) model (Corell and Corkhill, 1994)
- The West Van Buren (WVB) group model [Van Waters and Rogers (VWR)] for the WVB area (VWR, 1997).

The model domain extends from 56th Street west to 99th Avenue and from Camelback Road south to Dobbins Road, encompassing an approximate area of 180 square miles. The CPM was developed in three stages:

- Phase 1: Data compilation
- Phase 2: Developed the regional seasonal, transient groundwater flow simulating from 1972-1995
- Phase 3: Validated the model using additional data from 1996-1998.

In developing the CPM, WESTON constructed a finite-difference grid for the model area, specified the model structure, assigned boundary conditions, specified hydraulic parameter values and zones, and selected appropriate water-level measurements for calibration of the model. The model parameters are generally discussed herein and the reader is referred to the CPM Modeling Report, prepared by WESTON, the text of which is provided in Appendix C (WESTON, 2000). The text of the Model Validation Report is provided in Appendix D (WESTON, 2001).

3.1 Model Code Selection and Description

For the construction and calibration of the original three layer numerical groundwater flow model (TLM) for the CPM, WESTON selected the simulation program MODFLOW, a publicly-available groundwater flow simulation program developed by the USGS (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings.

MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, aerial recharge, injection or extraction wells, evapotranspiration, horizontal flow barriers (HFB), drains, and rivers or streams. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the CPM, which consists of a heterogeneous geologic system with variable unit thicknesses and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

After significant input from ADEQ-established Technical Exchange Meetings between WESTON, ADEQ, and interested parties within the regulated community during development of the TLM, the model was converted to a five layer numerical groundwater flow model (FLM). This effort was completed using MODFLOW-SURFACT (HydroGeoLogic, Inc., 1996) to account for a number of conditions found in the model domain (*e.g.*, pumping from wells that are screened in multiple hydrostratigraphic units to reallocate pumping from deeper zones when upper zones are dewatered). The graphical interface program Groundwater Vistas (GWV) was also used to facilitate data entry and the analysis of results (WESTON, 2000).

3.2 Model Domain

The CPM FLM uses a uniform grid of 80 rows by 144 columns with a nodal spacing of 660 ft. This grid spacing was used as it was easier to locate new wells in the model grid when the only location information was the cadastral location to the ten acre, quarter/quarter/quarter section. The five hydrologic units modeled are the two layers comprising the Upper Alluvial Unit (UAU_1, UAU_2), two layers within the Middle Alluvial Unit (MAU_1, MAU_2) and a portion of the LAU (WESTON, 2000). Model units are days and ft with all flow rates entered as cubic ft per day (ft^3/day) per model node.

The CPM model area is shown on Figure 10. This figure also depicts the locations for a series of hydrostratigraphic cross-sections. The main east-west cross-section is presented on Figure 11.

3.3 Simulation Period

The CPM simulates flow for a 27 year period beginning in 1972 and extending through 1998. To account for seasonality, each year is subdivided into three unequal stress periods, based on modeling completed for the VWR model (VWR, 1997). These stress periods were verified by reviewing Roosevelt Irrigation District (RID) pumping. The stress periods are as follows:

January & February: 10% annual pumping (59 days)

March - September: 84% annual pumping (214 days)

October - December: 6% annual pumping (92 days)

3.4 Hydraulic Conductivity Parameters

The UAU K value was initially set up for the steady-state model, then modified during steady-state calibration and the TLM development. The goodness of fit of the model calibration was determined through comparison of calculated and measured water levels. Where significant discrepancies between calculated and observed water levels existed, the aquifer test data used to develop the K array in the area of the discrepancy were reexamined and adjustments made to the model K array if warranted, or the elevation of the bottom of the UAU was reexamined to determine if a greater thickness of upper alluvium were present. Adjusting the thickness of the layer will result in a change in the model transmissivity. This process was repeated until a reasonable calibration was achieved between measured water levels and the model calculated water levels.

The UAU array used in the steady-state model was modified again when the FLM model was developed. At this time, the UAU was split into two sublayers, with the UAU_1 having higher K values and the UAU_2 having lower K values (WESTON, 2000). The K arrays for the MAU_1 and MAU_2 were set equal to those used in the SRV model, as was the LAU array (WESTON, 2000).

MODFLOW simulates vertical flow between layers as a result of a leakage between layers, dependent on vertical conductivity (Kv) and layer thickness (WESTON, 2000). According to WESTON, there are no data on Kv within the CPM area; therefore, the Kv was set to one-tenth the horizontal K. Vertical anisotropy within a layer was not used in the CPM other than to assure the Kv is one-tenth the horizontal K.

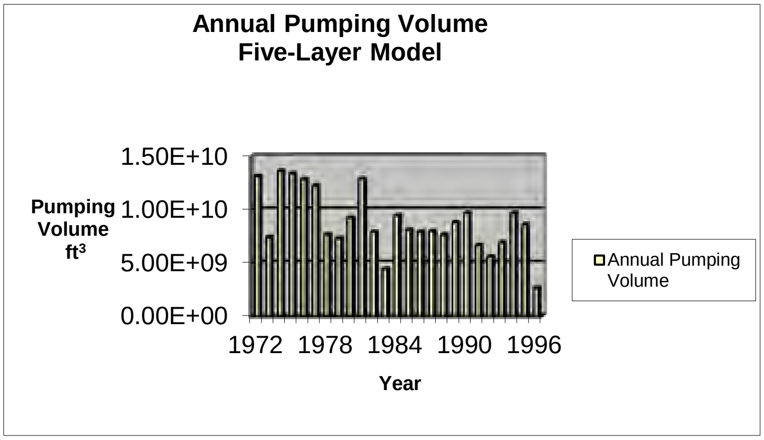
Values for K in the UAU within the model range from 100 ft/day up to 800 ft/day, near the Salt River. Figure 12 shows the K values for the upper portion of the UAU within the CPM.

3.5 Boundary Conditions: Sources and Sinks

The model boundaries for the CPM include all stresses on the aquifer system. A source (or inflow) is defined as an addition of water to the groundwater aquifer and a sink (or outflow) is defined as a removal of water from the aquifer. For the CPM, sources include recharge and flow across model boundaries. Sinks include pumping wells and flow across model boundaries.

3.5.1 Pumping

Groundwater pumping (or withdrawal) represents the major outflow from the groundwater system within the CPM study area. Annual pumping data were obtained from the primary agencies withdrawing the water (Salt River Project [SRP] and RID) from the ADWR files and databases, and from the VWR files (WESTON, 2000). The graph below shows pumping in cubic ft. There are 335 wells pumping water within the CPM area. Groundwater removal is generally divided between municipal and agricultural uses with these uses making up over 90 percent of the total. The remainder of the pumping is for industrial and private uses.



Of the 335 pumping wells within the CPM area, 15 wells extend into the LAU. Ninety-two extend into the MAU and are screened across both the MAU and UAU. The remaining wells are screened only within the UAU. Well yields range from large diameter irrigation wells that can pump 2,500 gallons per minute (gpm) to small diameter monitor wells that are only pumped during sampling (WESTON, 2000). For many of the wells that are screened across multiple aquifers, the pumping rates in the numerical model were assigned to different layers based upon the length of the screen in that interval and the relative K in different layers.

3.5.2 Recharge

Recharge represents a major inflow to the CPM groundwater system. The sources of the recharge include the infiltration of excess irrigation water, leakage from irrigation canals and laterals, effluent discharge to river channels, and naturally occurring recharge from flood flows along major drainages (*e.g.*, Salt River) (WESTON, 2000).

The locations of sources of groundwater recharge within the CPM area and the recharge for each source was estimated. Recharge values reported in the SRV model served as initial transient model inputs, but were modified during model calibration. In the CPM, one recharge value was assigned to each node. Figure 13 depicts recharge in the CPM.

3.5.2.1 Agricultural Recharge

Irrigated agriculture remains the dominant land use within the western portion of the CPM. Fields are irrigated using sprinklers, rows, flood and furrow application, and excess irrigation water historically applied to these fields reaches the local water table as recharge. It has been estimated that as much as 40 percent of the water is available to move beneath the plant root zone (WESTON, 2000).

A general reduction in agricultural acreage within the CPM area with time and more water efficient irrigation practices have decreased the volume of agricultural recharge. Given these conditions, it appeared that the volume of water reaching the aquifer within the CPM area would not vary significantly with time, but rather the most significant variation would be spatial, as agricultural lands were urbanized.

3.5.2.2 Urban Recharge

WESTON determined that the impact of recharge from the majority of urban sources within the CPM is generally negligible. Few urban lakes or heavily landscaped areas exist within the CPM area and those that are present do not appear to be large enough to contribute significant quantities of water to the aquifer. Recharge from urban areas was assumed to be negligible except in the Arcadia District in the northeastern part of the CPM where water levels are shallow and flood irrigation is used. Urban irrigation in the majority of the CPM area has minimal impact on recharge compared to agricultural irrigation because most excess urban irrigation run off is intercepted by storm sewers.

3.5.2.3 Canals

Canals transported water for irrigation purposes within the CPM area since before recorded history, and the present day canal systems convey a combination of groundwater and surface water from the Salt River (when available) from the eastern portion of the valley to agricultural users in the west. These canal systems have evolved from simple earthen ditches to concrete lined waterways and constitute a source of recharge to the local aquifer system. There are five major canals within the CPM transmitting water for irrigation, the Grand Canal, Roosevelt Canal, Western Canal, North Branch of the Highline Canal and the Arizona Canal.

The infiltration rates for the canals and laterals within the CPM area were taken directly from the ADWR's SRV model (Corkhill, *et al.*, 1993). The rates were developed by the SRP and the Bureau of Reclamation for lined and unlined canals (WESTON, 2000).

3.5.2.4 Salt River

The Salt River is the most significant surface drainage feature in the CPM area. Periodic winter and early spring frontal thunderstorms, coupled with runoff from melting snows along the upper watershed, can produce flow from the upstream dams. These events, although short in duration, contribute measurable recharge to the aquifer.

The Salt River historically had a major role in recharging the groundwater system in the CPM area. Prior to the construction of upstream dams, the river was perennial (Lee, 1905) and water was diverted from its channel for irrigation. During this time, the river was in direct hydraulic connection with the aquifer and provided a relatively continuous source of recharge. As flows in the river diminished following construction of upstream reservoirs, the Salt River has had an increasingly smaller role as a source of recharge.

Several attempts have been made to quantify the amount of recharge received by the aquifer during these events, but have been difficult to complete, because of a lack of gauging stations or other means of measuring the flow and its effects on recharge. In addition, if a particular year was wet enough to produce flood flows in the river channel, there was usually sufficient precipitation to reduce the need for heavy irrigation pumping.

The underlying conclusion of all of the research into Salt River recharge is that storm flows are highly localized and of little consequence from a volumetric standpoint (WESTON, 2000). However, storm flows are important in changing the direction of groundwater movement that may be experienced as a result of sudden rises in the water table.

3.5.2.5 Sewage Effluent from Wastewater Treatment Plants at 23rd Ave and 91st Ave

The only portion of the Phoenix area reach of the Salt River experiencing perennial flow is downstream from each of the City of Phoenix (COP) waste water treatment plants (WWTPs). At both the 23rd Avenue and 91st Avenue facilities, treated sewage effluent is discharged to the Salt River. Downstream of the 23rd Avenue WWTP, flow continues until about 67th Avenue (Corkhill *et al.*, 1993). Perennial flow resumes below the 91st Avenue plant and continues beyond the western limits of the CPM area. Groundwater recharge from these effluent flows is evident in the shape of the water table contours for the area. RID diverts a portion of this effluent to their canals for irrigation use, however, according to RID records, these diversions were minimal until late 1995.

3.6 Calibration and Sensitivity Analysis

Calibration targets are defined as “a point in space and time where one of the model dependent variables has been measured” (Environmental Simulations, Inc., 1998). Transient calibration targets in GWV can be head, concentration, or drawdown. The CPM used head values from 1982 and 1991 water level data, as well as data from well hydrographs. There are 156 locations in the CPM for which heads were available (WESTON, 2000).

As noted above, many of the wells are screened across multiple layers. GWV assigns the calibration targets to the layer in which the bottom elevation of the screen occurs. Of the 156 calibration target locations in the FLM, 70 were RID, SRP or COP pumping wells. Difficulties in using water levels collected from pumping wells arise because the data may not represent true static water levels but rather a flash static (measured when the wells are turned off, allowed to recover for a short period of time [usually a few minutes], and the water level measured).

The data were entered in the model as elapsed time from the beginning of the model (days since January 1, 1972). Obviously, the water level measurements used as calibration targets were not all measured on the same day (*e.g.*, the 1982 and 1991 data were measured over a two-month period). GWV accepts a time period during which all data will be considered. The time frame for the calibration targets for the CPM was ±30 days (WESTON, 2000).

The residual or difference between the model-calculated value and the measured value at the calibration target provides an evaluation of the ability of the model to simulate the aquifer conditions. Another method for evaluating a model calibration is to compare water level contour maps generated with the observed data with model-generated water level contour maps to qualitatively compare the flow direction, spacing of the contours and shape of the contours. Both methods were used in the CPM (WESTON, 2000).

4. Facility Groundwater Flow Model

As stated in Section 1.1, the Respondents have developed a Facility-specific transient groundwater flow model using the existing CPM, coupled with solute transport simulations to evaluate potential contaminant transport from the Facility. Consistent with the CPM groundwater flow model, MODFLOW-SURFACT (HydroGeoLogic, Inc., 2008) was used for groundwater flow simulations. The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires aerial and vertical discretization, or subdivision of the continuous aquifer system into a set of discrete blocks that form a three-dimensional model grid. In the block-centered finite-difference formulation used in these codes, the center of each grid block corresponds to a computational point or node. When MODFLOW solves the set of linear algebraic finite-difference equations for the complete set of blocks, the solution yields values of hydraulic head at each node (or three-dimensional block) in the three-dimensional grid.

Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (*i.e.*, a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

As presented in the CPM discussion in Section 3, the grid size in the regional groundwater flow model is 660 ft by 660 ft, which will not allow sufficient detail in the groundwater flow and solute transport at and in the vicinity of the Facility (The Facility covers an area of approximately 1,000 ft by 1,250 ft). Therefore, the development of a more refined sub-model to simulate the groundwater flow and solute transport was warranted at the Facility.

4.1 Model Mesh Refinement

The Facility groundwater model was developed from the CPM regional model using the telescopic mesh refinement (TMR) method, in which a larger encompassing model (the CPM) is used to define the boundary conditions and model parameters for a smaller embedded model (the Facility groundwater flow model) (Townley and Wilson, 1980; Buxton and Reilly, 1986; Miller and Voss, 1987; Ward, *et al.*, 1987). This is consistent with the USEPA's recommendations for use of the CPM at specific facilities within the Motorola 52nd Street Superfund Site (USEPA, 2000) The purpose of creating the Facility groundwater model is to provide the ability to refine the aerial finite-difference grid for more effective solute transport modeling without resulting in excessive simulation times due to undesired simulation of the entire CPM domain.

The pre/post processor GWV Version 5 (Environmental Simulations, Inc., 1998), which has the ability to perform TMR, was used to facilitate Facility model refinement. In addition, GWV was used to pre- and post-process the model results.

4.1.1 Model Domain of the Facility Groundwater Flow Model

The refined Facility groundwater flow model covers an aerial extent of approximately 42,900 ft by 22,700 ft (approximately 8.3 miles by 4.1 miles) (Figure 14). The boundaries of the model grid were set at a significant distance from the site location to minimize the influence of model boundaries on simulation results in the vicinity of the Facility. Accordingly, the model is bounded by 39th Avenue to the west, by 40th Street to the east, by McDowell Road to the north, and by Roeser Road to the south. The model row and column widths vary throughout the model domain and were based on the size of the area of interest, the total area of the model domain, and the degree of accuracy and precision needed. To improve the accuracy of the groundwater flow and solute transport analyses in the vicinity of the Facility, the grid spacing was refined from the original 660 ft by 660 ft in the CPM model to 10 ft by 10 ft at and immediately adjacent to the Facility. As distance from the Facility increases, the grid spacing then grades up to 100 ft by 100 ft in the remaining area of the model domain (Figure 14).

In the CPM, model layers 1 and 2 represent the Upper Alluvial Unit (UAU_1, UAU_2); model layers 3 and 4 represent the Middle Alluvial Unit (MAU_1, MAU_2), and model layer 5 represents a portion of the LAU. In the Facility model, the vertical structure of the CPM model layer 1 (UAU_1) was modified to more accurately reflect the current understanding of the hydrostratigraphy at the Facility. Based on a detailed review of boring logs and site cross-sections (Figure 9), and relevant regional publications, the CPM model layer 1 (UAU_1) was further divided into two layers, with the upper 60% of UAU_1 representing the shallow groundwater encountered at the Facility and the lower 40% of UAU_1 representing intermediate groundwater below. Therefore, in the Facility model, model layers 1 through 3 represent the UAU; model layers 4 and 5 represent the MAU, and model layer 6 represents LAU (Figure 15). The resulting three-dimensional finite-difference grid consists of a total of 1,137,006 grid nodes.

4.1.2 Hydraulic Parameters of the Facility Groundwater Flow Model

No change was made to the hydraulic parameters applied in the CPM. Since the focus of this modeling effort is in the shallow UAU, only the hydraulic conductivity zonation in model layers 1 and 2 are presented in Figure 16. As shown in the figure, the Facility is located in the K zone of 200 ft/day, which is consistent with the range (200 to 450 ft/day for Salt River Gravels) provided by Reynolds and Bartlett (2002), and with slug tests completed in the vicinity of the Facility as discussed in Section 2.6.2. To the east of the Facility, a hydraulic conductivity value of 100 ft/day was used. The hydraulic conductivity in the vicinity of the Salt River was assumed to be 800 ft/day, representing the more permeable river sediments. The permeability decreased with the increasing distance from the river, represented by the decreasing trend of the K values: 800 ft/day to 600 ft/day to 300 ft/day.

4.1.3 Boundary Conditions of the Facility Groundwater Flow Model

The Facility model retained all relevant boundary conditions from the CPM groundwater flow model. General head boundaries (GHBs) were incorporated along the Facility model extent in all six model layers to allow for the simulated regional inflow and outflow across the sub-model boundary (Figure 14). The stage elevations and conductance values of the general head boundaries in the Facility model were assigned directly from the simulated flow field from the CPM model. All relevant parameters for pumping wells, including well screen locations and pumping record, were retained from the CPM regional model, as shown in Figure 16.

4.2 Model Calibration

As discussed in Section 3, the CPM went through an extensive calibration and sensitivity analysis and validation. It was concluded that “It (the CPM) can be used to evaluate future remedial alternatives and provides a starting place for the evaluation of contaminant movement in the CPM area” (WESTON, 2001). Because the Facility groundwater flow model was developed from the CPM regional model, the model verification effort mainly focused on the comparison between the Facility groundwater flow simulation results and the CPM regional model simulation results. Specifically, the model verification was evaluated using (1) qualitative groundwater directions and gradients, (2) the model flux mass balance, and (3) the comparison of measured and simulated water levels with time using hydrographs.

4.2.1 Simulated Hydraulic Head Distribution

As the first step in the Facility model verification, the Facility model-simulated potentiometric surface maps were compared to those from the CPM groundwater flow model. Simulated potentiometric maps (UAU Model Layer 1) were prepared for December 1972, February 1981, September 1991, September 1993, and December 1998 and are presented in Figures 17A, 17B, 17C, 17D and 17E, respectively. As shown in these figures, the Facility simulated potentiometric maps are almost identical to those simulated by the CPM. As a result, the simulated groundwater flow directions and gradients are similar, indicating that the telescopic refinement in the Facility model preserved the flow conditions observed in the CPM. It is expected that the simulated water levels will vary slightly as the Facility model has the ability to resolve hydraulic gradients more accurately due to the refined computational grid.

Consistent with the CPM, groundwater generally flows to the west-southwest in the UAU. In the vicinity of the Facility, groundwater flow directions show a shift from west-southwest to a northwest direction, which is due to the floods produced by winter and early spring frontal thunderstorms coupled with runoff from melting snows along the UAU (WESTON, 2000). Therefore, groundwater at the Facility generally flows to the west with a slight southwest component during the non-flood season. During the flood season (a major flow event occurs in the Salt River [defined as flow at the Granite Reef Dam greater than 320,000 acre feet per year]) (WESTON, 2001), groundwater flow direction shifts to a northwest direction.

4.2.2 Simulated Water Flux

As an additional verification test of the Facility model, groundwater flux in and out of sources and sinks were compared between the Facility model and the CPM. To account for the transient flow conditions during the simulation period, model simulated groundwater inflows and outflows from two stress periods were compared: a stress period representing the flood season (September 1993, model stress period 65) and a second stress period (December 1998, model stress period 81) representing the non-flood season. The comparison results are summarized in Table 4.

A few pertinent observations can be made based on Table 4. First, during the non-flood season (normal flow conditions), the inflow from the Salt River is minimal (accounting for 7.3% of the total inflow in stress period 81), indicating that the Salt River played a small role as a source of recharge since the construction of upstream reservoirs (WESTON, 2000). The inflow of 15.2 cubic feet per second (cfs) from the Salt River represents the perennial flow occurring in the river downstream of the 23rd Avenue WWTP within the model domain. However, during the flood season, the recharge from the Salt River is approximately 153.6 cfs, accounting for 45.7% of the total model inflow for stress period 65. The recharge from the Salt River caused groundwater levels to rise up and influence the groundwater flow direction in the vicinity of the Facility. Secondly, the pumping wells extracted more water during the flood season (approximately 80 cfs) compared the non-flood season (approximately 18 cfs). And finally, the major flow sources and sinks simulated in the Facility model match those in the CPM well, suggesting that the Facility model successfully reproduced the CPM flow balance.

4.2.3 Hydrographs

As the final verification of the Facility model, the Facility model simulated hydrographs were compared with those from the CPM at selected monitoring wells. In addition, when there are observed water levels available, observed water levels were also included in the hydrographs. Hydrographs at AEW01-25, AEW01-95, AEW06-04, AVIS-01 and RID-113 (well locations shown in Figure 18A) were prepared to demonstrate the match between the Facility model and the CPM. These wells were calibration targets in the CPM and were also chosen because they are located in the vicinity of the Facility. In addition, the hydrograph at MW-4 (located immediately to the northwest of the AdobeAir Warehouse, shown on Figure 6) was also prepared because it is one of the two monitoring wells at the Facility with TCE detections above its MCL of 5 µg/L.

The hydrographs for these selected targets are presented in Figures 18B, 18C, 18D, 18E, 18F, and 18G, for MW-4, AEW01-25, AEW01-19S, AEW06-04, AVIS-01 and RID-113, respectively. MW-4 was installed in 1991 and water levels were measured in 1992 on quarterly basis and in December in 1994. These observed water level data are shown on Figure 18B, along with the Facility model and CPM simulated water levels. As shown on the figure, the Facility model simulated water level data match the observed data better than those simulated by the CPM. The difference between the two sets of model simulated water levels lies in the difference in the grid size within the two models. As discussed in the Section 4.1, the grid size of the Facility was refined to 10 ft by 10 ft in the vicinity of the Facility, compared to the grid size of 660 ft by 660 ft in the CPM. The refined grid resolution contributes to the improvement in the simulated water level in the Facility model.

At AEW01-19 (Figure 18D), both model-simulated hydrographs match the observed water level trend reasonably well, with the Facility model simulated water data showing a slight improvement in matching the observed data (*e.g.*, the relatively higher water level observed from December 1992 to January 1994).

At AEW06-04 (Figure 18E), both model-simulated hydrographs show a reasonable match with the observed water level magnitude from 1997-1998. However, both models were not able to simulate the slight water level increase observed in mid-1998 at AEW06-04.

At AVIS-01 (Figure 18F), the Facility model-simulated hydrograph matches the observed water levels in January and October of 1994 very well. As with all other targets, the Facility model simulates magnitude of the seasonal change in water levels better than the CPM.

Figure 18G shows the model-simulated hydrographs and the observed water level at RID-113. The two model simulated hydrographs show the least discrepancy in simulated water levels among all targets, likely because water levels at RID-113 were more controlled by the pumping rates, and therefore, less likely to be influenced by the grid resolution of the models. Both model-simulated hydrographs match the observed water levels very well.

In general, the Facility model-simulated water levels are consistent with those simulated by the CPM. Both models successfully reproduce the general water level trends due to the changes in recharge from the Salt River. In addition, the Facility model was able to simulate the minor seasonal change in the water levels, which the CPM failed to do. In summary, the Facility model was verified and is suitable as a basis for the solute transport model to evaluate the potential for TCE migration at the Facility.

5. Solute Transport Model

Following verification of the Facility model, a solute transport component was developed to simulate the fate and transport of TCE. The transport model codes, potential TCE source area, parameters that control migration of TCE, and simulations carried out to address the uncertainties associated with the solute transport simulations are discussed in detail in the following sections.

5.1 Code Selection and Description

MODFLOW-SURFACT, a fully integrated groundwater flow and solute transport model that uses state-of-the-art numerical schemes for solving the transport equation, was selected for the solute transport simulation. The Total Variation Diminishing flux limiting schemes included in the code are designed to provide accurate, physically correct, and strictly mass-conservative numerical solutions. An adaptive implicit scheme is used to minimize temporal discretization errors. The matrix equations resulting from the finite-difference approximations are solved using an efficient Orthomin matrix solver. The primitive mass-conservative form of the transport equation is used, providing strictly mass-conserved numerical solutions.

In this solute transport model evaluation, the dual-domain mass transfer model, an alternative to the classical single-domain advection-dispersion equation, was utilized.

The classical Fickian advection-dispersion transport equation for contaminant solute in a single domain (Freeze and Cherry, 1979) can be written as below:

$$\theta \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij} \frac{\partial C}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(q_i C) + q_s C_s \qquad (1)$$

Where:

C is the solute concentration,

θ is the porosity, t is time,

x_i is the horizontal coordinate (east-west direction),

x_j is the transverse coordinate (north-south direction),

D_{ij} is the dispersion coefficient tensor,

q_i is the Darcy flux,

q_s is the fluid source/sink, and,

C_s is the concentration of fluid source/sink

In a dual-domain model, two porosity terms need to be specified: mobile and immobile porosity. Mobile porosity represents the more mobile portion of the formation where advective transport dominates, whereas the immobile porosity represents the less mobile portions of the formation where diffusion is dominant. The dual-domain model more accurately explains the classic movement of contaminants in the subsurface than the single-domain model. Typically, as a pulse of contamination migrates through porous media, portions of the plume move quickly in the migratory pore space while other portions of the plume diffuse and migrate into less mobile zones. Eventually, as the bulk of the plume mass migrates past a point in the system, mass stored in the less mobile zones diffuses or contributes mass back into the more active pore space through diffusion (Gillham *et al.*, 1984). Mass transfer into and out of the less mobile zone is generally slow since the process is controlled by diffusion. This effect is described clearly in the literature as well as the mathematics to support the concept (Gillham *et al.*, 1984; Molz *et al.,* 2006; Flach *et al.*, 2004; Harvey and Gorelick, 2000; Feehley *et al.*, 2000; Julian *et al.*, 2001; and Zheng and Bennett, 2002).

The following expression describes the dual-domain model for a given contaminant:

$$\theta_m \frac{\partial C_m}{\partial t} + \theta_{im} \frac{\partial C_{im}}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta_m D_{ij} \frac{\partial C_m}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(q_i C_m) + q_s C_s \qquad (2)$$

$$\theta_{im} \frac{\partial C_{im}}{\partial t} = \beta (C_m - C_{im}) \qquad (3)$$

Where:

C_m is the solute concentration in the mobile domain,

C_{im} is the solute concentration in the immobile phase,

θ_m is the porosity of the mobile domain,

θ_{im} is the porosity of the immobile domain, and

β is the first-order mass transfer coefficient between the mobile and immobile domains.

Note: $\theta_{total} = \theta_{im} + \theta_m$

5.2 Potential Source Areas

In order to evaluate the TCE migration at the Facility, it is important to delineate TCE concentrations and extent in the source area as accurately as possible. As discussed in Section 2.3, a series of source area investigations were conducted at the northwest corner of the Facility. These investigations include the soil vapor survey conducted by SA&B-contracted Tracer Research Corporation (TRC) of Tucson, Arizona, in July 1993 and various soil sampling events that were carried out between 1989 and 2004 in the northern portion of the Facility. These investigation events indicate that the major source area was located in the concrete storage tanks and solution vessels. The TCE extent applied in the model was based on the soil gas delineation and is shown in Figure 19.

The VLEACH model simulation conducted by SA&B in 1995, at the request of ADEQ, was used to determine the TCE source strength. As summarized in Section 2.3.4, the VLEACH model predicted a TCE concentration of 115.4 micrograms per liter (µg/L) in the first year, decreasing to 90.3 µg/L in year 100 (SA&B, 1995). These values are somewhat higher than observed at the Facility which vary from 12 to 59 µg/L over the modeling period of record. ADEQ concurred that the VLEACH simulation is overly conservative and its potential to overstate potential contamination in groundwater. However, to address in the uncertainties associated with the source area, conservative assumptions were made in this solute transport evaluation. Based on the VLEACH model results, a constant TCE concentration of 100 µg/L was applied in the model to represent the TCE source during the model simulation period (1972-1998), which is a conservative assumption since actual TCE concentrations in the source area have decreased over this period.

5.3 Transport Parameters

The simulation of contaminant fate and transport requires specification of various transport parameters that control the rate, movement, mixing, and absorption of COCs in the subsurface. For the updated transport modeling analysis, the model simulations of the COC fate and transport at the Facility were conducted incorporating the processes of advection, dispersion, adsorption, and degradation.

Advection defines the process of contaminant migration due to the movement of groundwater. In groundwater hydrology, dispersion is traditionally called hydrodynamic dispersion (Bear, 1972), which includes molecular diffusion and mechanical dispersion. Molecular diffusion is generally secondary and negligible compared with the effects of mechanical dispersion. Mechanical dispersion is mixing caused by local variations in velocity around the mean flow velocity, and it is described with the mechanical dispersion coefficient. Adsorption refers to the partitioning of a contaminant between the liquid and solid phases of the aquifer. In this case, degradation refers to biodegradation of volatile organic compounds through natural attenuation (*e.g.*, reductive dechlorination of TCE to cis-1,2-DCE).

All numerical models have inherent limitations and uncertainties associated with the simplifying assumptions when used to describe these processes occurring in real subsurface conditions. In order to address the uncertainties associated with the numerical modeling (to the extent possible), three scenarios were simulated in the solute transport modeling as described below:

1. Scenario 1a: Base Case
2. Scenario 2: More Conservative Case
3. Scenario 3: Less Conservative Case

The dual-domain approach was applied in all scenarios. Scenario 1a Base Case represents the most likely case to describe the COC fate and transport at the Facility, in which reasonable dual-domain and transport parameters were assumed. Scenario 2, a more conservative case, uses the lower limit total porosity (0.28) in the dual-domain approach and conservative transport parameters. For this study, conservative implies that parameters are used that will result in elevated concentrations and larger transport distances. Scenario 3 represents a less conservative case in which the upper limit of porosity (0.50) was used in the dual-domain approach and less conservative transport parameters were used in the simulation. In addition, to illustrate the sensitivity of various transport parameters on the COC fate and migration, additional simulations were carried out that vary all of the key transport parameters, as described below and summarized in Table 5:

- Scenario 1b: to evaluate the sensitivity of immobile porosity q_{im} ;
- Scenario 1c: to evaluate the sensitivity of degradation (COC half life); and
- Scenario 1d: to evaluate the sensitivity of adsorption.

5.3.1 Advection

The advection process was defined by the groundwater flow simulation as described in Section 4. As noted previously, solute transport simulations for the Facility were performed using the dual-domain approach. The total porosity, mobile/immobile porosity estimates were varied for the UAU only, since COC migration has only occurred in the shallow UAU (Model Layer 1).

The dual-domain approach requires assignment of two porosity terms: mobile (q_m) and immobile porosity (q_{im}). Because site-specific total porosity values are not currently known, the range of porosity values (0.28 to 0.50) estimated in the region (including those by CH2MHILL [2003] and Rosenbloom *et al.*, [2006]) were applied in different scenarios. Specifically, as summarized in Table 5, the mobile porosity and immobile porosity values are 0.20 and 0.17, respectively, in Scenarios 1a, 1c and 1d, representing a most likely case to describe the Facility conditions. In Scenario 2, the most conservative case, the lower limit of total porosity 0.28 was applied in the model simulation. The mobile and immobile porosity values are 0.20 and 0.08, respectively, in Scenario 2. The low porosity in Scenario 2 would increase the COC migration velocity and add conservatism in the simulation. In the less conservative Scenario 3, a total porosity value of 0.50 was applied, which is on the high-end of the porosity value range. The mobile and immobile porosity values were set as 0.25 and 0.25, respectively. These values would represent the upper range of values for silt, sand and gravel observed in the UAU. The relatively high porosity values applied in Scenario 3 would slow down the COC migration from the Facility; therefore, the model simulation will resule in shorter distance travel during the simulation period.

In addition, the Scenario 1b simulation was conducted to compare the results with Scenario 1a to assess the sensitivity of mobile/immobile porosity values in the model simulations. In Scenario 1b, the immobile porosity was reduced from 17 percent to 8 percent. The reduction in immobile porosity was expected to potentially increase the migration and spreading of the COC plume since less immobile pores would be available for COC mass transfer from the mobile pores.

Because of the suspected age of the plume (*i.e.*, assumed to begin immediately after the tanks were installed [reportedly in 1962], or approximately 50 years old) it was assumed that the mobile and immobile domains are in equilibrium. Therefore, the immobile domain concentrations were assumed to be equal to the mobile domain concentrations (*i.e.*, dissolved phase concentrations). This initialization approach provides conservative results because additional contaminant mass is simulated in the solute transport model. Literature reported mass transfer coefficients for two domains range from 0.0001 day^{-1} to 0.001 day^{-1} (Gillham *et al.*, 1984; Molz *et al.*, 2006; Harvey and Gorelick, 2000; Feehley *et al.*, 2000). A mass transfer coefficient of 0.0005 day^{-1} was utilized in this updated transport modeling analysis and was based on current research (Zheng and Bennett, 2002).

5.3.2 Dispersion

In three-dimensional simulations, the dispersion process is defined by three components: longitudinal dispersivity, horizontal transverse dispersivity, and vertical dispersivity. In general, accurate calculation of the dispersion coefficients is difficult and must rely on rough estimates. There are several methods for estimating the longitudinal dispersivity. The longitudinal dispersivity value selected for the transport model is based on the relationship between dispersivity and observation scale as shown by Gelhar et al (1992). An observation scale of 1,000 meters (m) was selected as a reasonable initial estimate of the overall plume length. Based on Figure 2 of Gelhar (1992), an estimated plume length (observation scale) of 1,000 m results in a longitudinal dispersivity of approximately 25 m, or 80 ft.

In the absence of site-specific data, the transverse dispersivity can be taken as one order of magnitude less than (one-tenth) the longitudinal dispersivity and the vertical dispersivity can be taken as two orders of magnitude less than (one one-hundredth) the longitudinal dispersivity (Zhen and Bennett 1995).

Therefore, the transverse and vertical dispersivities were set to be 8 ft and 0.8 ft, respectively. Additionally, in Scenario 2, the most conservative case, no dispersivity was applied to evaluate the impact on COC migration in model simulations. Note that a limitation of the finite-difference scheme applied by the Modular Three-Dimensional Multispecies Transport Model ([MT3DMS], Zheng and Wang, 1999) is that some numerical dispersion is inherent in the simulation results. Numerical dispersion is a function of the size of the grid cell spacing, hydrogeologic properties assigned in the model, simulated water levels, and the time step size. The numerical dispersivity can be computed on a block-by-block basis in models solved using finite difference methods (Zheng and Bennett, 2002). Application of the equations reported by Zheng and Bennett (2002) indicates that the numerical dispersivity is approximately one-half the modeled grid size (approximately five ft for this analysis in the Facility area).

5.3.3 Adsorption

Adsorption parameters, such as the organic carbon fraction (f_{oc}) and the organic carbon adsorption coefficients (K_{oc}) for the COCs, were not available for the Facility. Those values suggested by ADEQ were used in the model simulations. The f_{oc} value utilized in this updated transport analysis was 0.2% (ADEQ, 2008). The K_{oc} value of 166 liters per kilogram (L/kg) for TCE was applied in the model (USEPA, 2002). The bulk density of 1.7 L/kg for the UAU was used in the model (USEPA, 1996). Retardation is simulated in the solute transport model based on the distribution coefficient, total porosity and soil bulk density. Considering the total porosity of 0.37, 0.28 and 0.50 in Scenarios 1, 2 and 3, the retardation factors due to adsorption are 2.5, 3.0 and 2.1, respectively. This indicates that Scenario 1 is intermediately conservative, Scenario 2 is more conservative and Scenario 3 is less conservative.

5.3.4 Degradation

Degradation refers to the mass decay of a solute due to physical, chemical, and biological activity. The solute transport model simulates the degradation of TCE and the generation of its daughter product cis-1,2-DCE. Consistent with other solute fate and transport parameters describing COC migration at the Facility, a range of degradation rates were applied in different simulation scenarios. Aronson and Howard (1997) states that "a range of recommended values again seems most appropriate for this compound [TCE] with the lower limit equal to 0.00014/day (half-life of 4,950 days), which was the lowest measured field value, to 0.0025/day (half-life of 277 days), which is the mean value for the field/*in situ* microcosm data set." Therefore, as summarized in Table 5, the lower limit of degradation rate of 0.00014/day (half-life of 4,950 days) was applied in the most likely case Scenario 1a, as supported by Facility data that TCE degradation to cis-1,2-DCE occurred at the Facility by cis-1,2-DCE detections (ARCADIS, 2011d). Additionally, Scenario 1c was conducted to evaluate the sensitivity of simulation results to the TCE half life. In Scenario 1c, degradation was not applied, representing a more conservative estimate compared to Scenario 1a. Nor was TCE degradation applied in Scenario 2. However, in Scenario 3, the upper limit rate of 0.0025/day (half –life of 277 days) was used to simulate a more aggressive TCE degradation rate in order to represent a less conservative simulation.

5.4 Transport Simulation Results

The following sections describe the simulation results for the COC fate and transport in the vicinity of the Facility in different scenarios.

5.4.1 Scenario 1a- Base Case

Scenario 1a, the Base Case, represents the most likely scenario for the solute fate and transport at the Facility. Therefore, the model simulation results were discussed in more detail than the other scenarios. The model simulation was carried out for 27 years, from 1972 through 1998.

The model simulated TCE extent maps were prepared for December 1972, February 1981, September 1991, September 1993, and December 1998 and are presented in Figures 20A, 20B, 20C, 20D and 20E, respectively. Model-simulated TCE concentrations at MW-4, representing the source area concentration profile, are presented in Figure 21A, along with model-simulated water levels. TCE concentrations observed at MW-4 at the Facility are also included in Figure 21A. In addition, two arbitrary TCE concentration targets (Plume Core Target and Plume Front Target), located downgradient of the Facility (shown on the Figure 20 series), were chosen to demonstrate the TCE migration behavior. The TCE concentrations at the Plume Core Target and Plume Front Target locations were plotted versus time on Figures 21B and 21C, along with the model simulated water levels.

As shown in Figures 20A through 20E, TCE migration from the northwest corner of the Facility follows groundwater flow directions. Groundwater flows to the west-southwest under normal conditions and to the northwest during flood season. As a result, TCE plumes were oriented in the south-southwest in 1972, 1991 and 1998 (Figures 20A, 20C and 20E). TCE plumes were oriented to the northwest in 1981 and 1993, as a result of the northwesterly groundwater flow directions produced during significant flooding events in the Salt River observed during these two years (see the Figure 18 series of hydrographs). The TCE plume migrates approximately 2,500 ft downgradient of the source area over the 27-year period of model simulation.

The TCE concentration profile at MW-4 (Figure 21A) also demonstrates the shifts in TCE migration pathways. MW-4 is located right downgradient west of the source area. Therefore, under normal conditions, MW-4 is located within the TCE migration pathway and TCE concentrations were relatively high in seasons with normal conditions. Under flood conditions, such as in 1981 and 1993, TCE concentrations at MW-4 were relatively low because the majority of TCE mass was carried by groundwater flow towards the northwest. The maximum TCE concentration of 59 µg/L at the Facility was observed on July 20th, 1992, which was under normal conditions prior to the flood in 1993. The magnitude of the peak TCE concentration observed at MW-4 is consistent with the model simulated peak concentrations under normal conditions, indicating that the model assumptions and transport parameters are reasonable. Note that TCE concentrations at MW-4 are not only affected by the groundwater flow directions, but also by the potential residual mass in the capillary zone above the groundwater table. In addition, a constant TCE source was applied in the model to add conservatism to the model simulation. The current TCE source concentration might be substantially lower than the simulated source concentration, based on the relatively low TCE concentrations at the Facility. The observed TCE concentrations have remained relatively low since 2005, consistent with the northwestern groundwater flow direction observed at the Facility in recent years (note that model simulation period ends in 1998). Under normal conditions when groundwater levels were relatively low, groundwater flows to the west-southwest, TCE concentrations were relatively high. During the flood seasons, due to the TCE migration direction shifting to the northwest, TCE concentrations were relatively low.

5.4.1.1 Scenario 1b – Immobile Porosity Sensitivity Analysis

Scenario 1b was carried out to evaluate the sensitivity of the simulated TCE migration extent to the dual-domain parameters. The assumed total porosity was 0.37 with a mobile porosity of 0.20 and an immobile porosity of 0.17. It was assumed that the 0.20 of mobile porosity is reasonable in representing the Salt River Gravels aquifer. In the dual-domain approach, the lower the immobile porosity value is, the less conservative, because a lower immobile porosity indicates that less TCE mass will be able to migrate into the immobile zone, leaving more mass in the mobile zone, which will result in more extensive TCE plume spreading. Therefore, a lower immobile porosity value was tested. Based on the site characterization in the vicinity of the Facility, the lowest total porosity tested was 0.28 (CH2MHILL, 2003). Therefore, a mobile porosity of 0.20 and an immobile porosity of 0.08 were assumed in Scenario 1b. The model-simulated TCE plume at the end of 1998 is presented in Figure 22A. For comparison purposes, the model simulated TCE extent in Scenario 1a (5 µg/L contour line in Figure 20D) is also shown in Figure 22A. Compared to the plume configuration in Scenario 1a, the TCE plume extent in Scenario 1b is similar, with TCE migration approximately 200 ft further downgradient, This indicates that model simulation results are not sensitive to immobile porosity values in the dual-domain approach.

5.4.1.2 Scenario 1c – Degradation Sensitivity Analysis

Scenario 1c was conducted to assess the TCE degradation rate sensitivity in the model simulations. Because of the detection of cis-1,2-DCE at the Facility, the lowest (or longest) TCE half-life observed in the fields and in the microcosm studies was applied in Scenario 1a model simulation (as discussed in Section 5.3.4). To evaluate the impact of TCE degradation rate on the TCE plume migration, it was assumed that there is no degradation of TCE in this Scenario. The model-simulated TCE plume at the end of 1998 is shown in Figure 22B, along with the TCE plume extent in Scenario 1a. Similar to the plume extent in Scenario 1b, the extent of TCE plume in Scenario 1c extends approximately 200 ft further downgradient, but remains similar to that of Scenario 1a, indicating that the relatively long TCE half-life assumed in Scenario 1a does not affect the TCE plume configuration significantly.

5.4.1.3 Scenario 1d – Adsorption Sensitivity Analysis

The sensitivity of adsorption parameters were evaluated in Scenario 1d. The partitioning coefficient K_d (the product of F_{oc} x K_{oc}), provides a retardation mechanism to slow down TCE migration in the model simulation. Consistent with the conservative approach, the lower K_d, resulted from a lower F_{oc} (0.001 compared to the 0.002 in Scenario 1a), which was applied in Scenario 1d. The lower K_d value will reduce the retardation and expedite the TCE plume migration, as evidenced by the slightly more extensive TCE plume in Figure 22C. The similar TCE extent in Scenario 1d suggests that adsorption is not a key process in controlling the plume migration.

5.4.1.4 Scenario 1e – Plume Stability Analysis

The peak TCE concentration profiles at MW-4, plume core target location, and plume front target location all indicate that the plume has been relatively stable (*i.e.*, plume configuration may extend slightly in years to come, but not significantly), as shown by the similar magnitude of peak concentrations in 1990s (*e.g.*, the peak observed in 1991 compared to that in 1997 in Figure 21C). To further demonstrate that the TCE has reached a relatively stable state, the solute transport model simulation period was extended from 1998 to 2011. An update on the model simulation period from 1998 to 2011 requires a significant amount of time. Therefore, it was decided that "being able to capture the hydrogeological trends in the area" in the extended model simulation should be satisfactory in this stability analysis. To achieve this, the hydrogeological conditions during the last cycle (from 1992 to 1998), in which a flood event of 1993 is included, were repeated twice to represent the groundwater flow trends from 1999 to 2011. The purpose of this exercise was to further demonstrate that the TCE plume has truly attained relative stability. The model-simulated plume extent is shown in Figure 22D. As shown in the figure, the plume configuration extends slightly further downgradient (approximately 200 ft), but not significantly. The TCE concentrations at the plume front target are shown in Figure 23, with the extended simulation period from 1999 to 2011. The model simulation results show that TCE concentrations at the plume front continued to increase from 1972 until early 1990s. In early 1990s, TCE concentrations appeared to approach a stable concentration, with a TCE concentration increase of only about 2 μg/L over a two-decade period (from early 1990s to 2011). The TCE plume extent and TCE concentrations at the plume front confirm that the TCE plume at the Facility is generally stable.

5.4.1.5 Summary of Scenario 1 Results

In summary, the TCE migration from the Facility is dominated by regional and local groundwater flow directions. As a result, the TCE plume migrated in the west-southwest direction under normal hydrologic conditions. However, during the flood season, the TCE plume migrated in the northwest direction due to the rise in the groundwater levels resulting from recharge from the Salt River. Note that in the areas further downgradient of the Facility, groundwater flow directions continue to trend to the west, as the influence of Salt River diminishes and the regional components dominate. Groundwater flow directions in the western portion of the model domain are heavily influenced by groundwater withdrawals. Other transport processes, such as degradation and adsorption, affect the TCE migration, however, have less influence than advection.

To estimate the maximum TCE migration extent due to the release at the Facility, a composite TCE plume was prepared using all model simulated historical TCE configurations (some TCE plumes were oriented towards west-southwest and the others were oriented to the northwest). The conservative simulation results from Scenario 1e, were also factored into the maximum composite TCE plume, presented in Figure 24. The maximum composite TCE plume extent was prepared encompassing the TCE plume with concentrations greater than 5 μg/L. The maximum distance to TCE migrated from the northwest corner of the Facility is approximately 2,500 ft. As demonstrated in the figure, TCE originated from the Facility does not appear to contribute to the OU3 plume. Additionally, TCE originated from the Facility does not impact the groundwater quality in the RID wells.

5.4.2 Scenario 2- More Conservative Case

Due to the uncertainty associated with the nature of source release and COC migration in the subsurface, a more conservative case, Scenario 2 simulation was carried out to thoroughly evaluate the potential plume migration to the extent possible. In this case, all transport parameters were set to be conservative. Specifically, the mobile and immobile porosity values were set at 0.20 and 0.08, respectively. Dispersivity was also excluded from the model. However, a minimum numerical dispersivity of approximately five ft remains in the model analysis and cannot be removed, even though cis-1,2-DCE was detected at the Facility indicating the occurrence of biodegradation. Biodegradation of TCE was neglected in this scenario. Lastly, it was assumed that no adsorption would have occurred at the Facility, which is very unlikely. As a result, this scenario was configured to represent a case that is extremely conservative, at the same time, unlikely to represent actual Facility conditions. The purpose of this simulation is to present the worst case of TCE migration and minimize the uncertainty associated with the TCE fate and transport evaluation.

The modeling results for Scenario 2 are shown in Figure 24. Consistent with Scenario 1, a maximum composite TCE plume encompassing all model simulated historical plume configurations were prepared. The maximum distance to TCE migrated from the northwest corner of the Facility is approximately 3,000 ft. As evidenced by Figure 24, even in the worst case scenario, TCE originating from the Facility does not appear to contribute to the OU3 plume, nor does it impact the groundwater quality in the RID wells.

5.4.3 Scenario 3- Less Conservative Case

In the less conservative case Scenario 3, transport parameters were configured such that the model simulation results provide a less conservative estimate of the potential TCE migration. For this simulation, the mobile and immobile porosity values were both assumed to be equal to 0.25, which were estimated from the upper limit of total porosity of 0.50 (PNI, 2006). The upper limit of total porosity value application would slow down TCE migration in the model, hence a shorter TCE migration distance, suggesting a less conservative case. Dispersion process was represented using the same dispersivity values as those in Scenario 1. The adsorption term was simulated using the same values as those in Scenario 1a. However, the upper limit of the half-life estimated in the field/microcosm studies was used in Scenario 3. The half-life was assumed to be 277 days, which equals to a degradation rate of 0.0025 per day (Aronson and Howard, 1997). This assumption results in an aggressive amount of TCE degradation. The minor cis-1,2-DCE observed in the aqueous phase at the Facility suggests much less aggressive TCE degradation. Therefore, this simulation tends to represent a less conservative case, at the same time, less likely to occur in reality as well.

The modeling results are included in Figure 24 as well. Due to the more aggressive assumptions made in this scenario, the TCE plume extent is much smaller, compared to Scenarios 1 and 2. The maximum distance that TCE migrated is approximately 1,000 ft downgradient. The TCE plume developed from the release at the Facility in this Scenario does not appear to contribute to the OU3 plume, nor does it impact the groundwater quality data in the RID wells.

6. Uncertainties and Limitations

Based on the understanding of regional groundwater flow conditions, the known site conditions, and calibration results of the numerical model, the groundwater flow and solute transport model can be used simulate the migration of TCE originated from the northwest corner of the Facility. However, this model includes fundamental simplifying assumptions regarding aquifer conditions and TCE migration behaviors. Therefore, this model has inherent limitations and uncertainties when used to describe real systems. The amount of uncertainty associated with the model results is directly related to the degree that actual site conditions deviate from model assumptions and input parameter values, including:

- **Boundary Conditions:** The Facility groundwater flow model was developed from the CPM regional model using the TMR technique. Therefore, the uncertainty associated with the boundary conditions in the CPM regional model is inherited. As discussed in the regional groundwater flow model section, Groundwater flow regimes in the CPM area are dominated by regional pumping centers with recharge supplied from excess agricultural irrigation, canal leakage, and occasional flood events. Groundwater movement within the region is predominantly controlled by the areal distribution of recharge and pumping. However, well construction information for many of the wells in the area, including well depths and perforated intervals, are not available. In addition, the “bedrock highs” in the eastern and north-central part of the CPM regional model, which exert some influence on the groundwater flow conditions, should be further reviewed.

- **Hydraulic Conductivity:** The model hydraulic conductivity values were estimated based on regional data and available site data. Hydraulic conductivity can vary several orders of magnitude over short distances which significantly affect model predictions. Additional aquifer test data for the entire basin should be considered in delineating the permeability of these aquifers.

- **Transport Parameters:** The transport parameters were estimated from available literature sources for geologic settings similar to those observed at the Facility and based on the qualitative solute transport calibration. The transport calibration was conducted using a limited historic dataset and assumptions regarding plume development over time which may significantly affect the estimated parameter values.

In summary, conservative parameters were applied when there is uncertainty associated with the physical processes in the numerical model simulations. However, due to the nature of numerical modeling, uncertainty is inherent and has been minimized to the extent possible, but cannot be eliminated in this modeling effort.

7. Summary of Modeling Activities and Conclusions

The CPM, which was deemed appropriate to be used to evaluate future remedial alternatives and provides a starting place for the evaluation of contaminant movement in the CPM area (WESTON, 2001 and USEPA 2000), was used to develop the Facility groundwater flow and solute transport model. Improvements to the original groundwater flow model include the following:

- Modifications to the original model vertical structure to more accurately reflect the current understanding of the hydrostratigraphy at the Facility. The shallow unit of the UAU was divided into shallow and intermediate units of the UAU, based on a detailed review of boring logs (site-specific as well as available regional boring logs), cross-sections, and relevant regional publications.

- The model grid spacing was refined from the original 660 ft by 660 ft in the regional CPM model to 10 ft by 10 ft in the vicinity of the Facility to achieve the accuracy and precision required for the solute transport model.

The developed Facility groundwater flow model was verified by comparing the model simulation results to those from the CPM regional model simulation: (1) the hydraulic head distributions, (2) water flux within the model domain, and (3) hydrographs at select monitoring wells within the model domain. The verification results indicate that the revision in the facility groundwater flow model actually improved the model in simulating the actual groundwater flow conditions. The facility groundwater flow model was then used as a basis for the solute transport model.

The purpose of creating a sub-model was to provide the ability to refine the computational grid for more accurate transport modeling without resulting in an overly cumbersome model (excessive simulation times, etc.). The solute transport model was developed and transport simulations were performed for TCE emanating near the northwest corner of the Facility. Uncertainty associated with the transport parameters was addressed through a series of simulations to thoroughly evaluate the sensitivity of relevant transport parameters. Three scenarios were simulated, including: Scenario 1a-Base Case, representing the most likely scenario, Scenario 2, a more conservative case, and Scenario 3, a less conservative case. In addition, model simulations were carried out to evaluate the individual sensitivity of relevant transport parameters, such as the immobile porosity value (Scenario 1b), TCE half life (Scenario 1c), and adsorption parameters (Scenario 1d). In addition, Scenario 1e was conducted to demonstrate that the TCE plume has achieved relative stability and no significant plume expansion is expected at the Facility in the future.

The extensive solute fate and transport simulation results indicate the following:

- TCE migration and plume position is controlled by regional groundwater flow directions and may range from southwest to northwest;
- TCE migration and plume extent was marginally affected by variations in the primary transport parameters;

- TCE migration has attained relative stability and no significant further expansion of the TCE plume is expected at the Facility in the future;
- TCE originated from the northwest corner of the Facility and does not appear to contribute to the OU3 plume. In addition, TCE originated from the Facility is not expected to impact the groundwater quality in the RID wells.

8. References

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Table 1 Summary of Historic Soil Sample Analytical Results M52 Constituents of Concern[a]
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Location	Date	Sample Location [(1)]	Sample Designation	Depth [(2)] (feet bgs)	1,1,1-TCA	1,1,2-TCA	1,1-DCA	1,2-DCA	1,1-DCE	1,4-Dioxane	Chloroethane	cis-1,2-DCE	PCE	1,2- DCE (Total)[(3)]	trans-1,2-DCE	TCE	Vinyl chloride
	ADEQ Residential Soil Remediation Levels (r-SRLs)[(4)]				**1,200**	**0.74**	**510**	**0.28**	**120**	**50**	**3.0**	**43**	**0.51**	**NE**	**69**	**3.0**	**0.085**
	ADEQ Non-residential Soil Remediation Levels (Non-res SRLs) [(4)]				**1,200**	**16**	**1,700**	**6.0**	**410**	**1,600**	**65**	**150**	**13**	**NE**	**230**	**65**	**0.75**
	ADEQ Minimum Groundwater Protection Level (GPL) [(5)]				**1.0**	**NE**	**NE**	**0.21**	**0.81**	**NE**	**NE**	**4.9**	**1.3**	**NE**	**8.4**	**0.61**	**NE**
	USEPA Regional Screening Levels Residential Soils(r-RSLs)[(6)]				**8,700**	**1.1**	**3.3**	**0.43**	**240**	**4.9**	**15,000**	**160**	**21.9**	**700**	**150**	**0.91**	**0.06**
	USEPA Regional Screening Levels Industrial Soils (i-RSLs) [(6)]				**38,000**	**5.3**	**17**	**2.2**	**1,100**	**17**	**61,000**	**2,000**	**111**	**9,200**	**690**	**6.4**	**1.7**
					USEPA Method 8010 (mg/kg)												
Northern	11/8/1989	SW of Concrete Tank Structure	R1-1-1A	4	0.010	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	<0.002	<0.002	NA	<0.002	<0.002
	11/8/1989	SW of Concrete Tank Structure	R1-1-1B	9	0.005	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	<0.002	<0.002	NA	<0.002	<0.002
	11/9/1989	NE concrete Tank Structure	R1-1-2B	10	0.019	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	0.005	0.003	NA	0.037	<0.002
	11/8/1989	SW Concrete Tank Structure	R1-1-3A	5	<0.002	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	<0.002	<0.002	NA	<0.002	<0.002
	11/8/1989	East of Gasoline Underground Storage Tanks	R3-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/11/1991	MW-4	MW4-10'	10	<0.010	<0.010	<0.010	<0.010	<0.010	NA	<0.010	NA	<0.010	<0.010	NA	<0.010	<0.010
	12/13/1991		MW-4-38'	38	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse	SS1	8.3	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.025	NA	<0.01	<0.01	NA	0.2	<0.025
	8/31/1994	Outside Northern Boundary of Warehouse (~27 feet SW of SS1)	SS2	7.3	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.025	NA	<0.01	<0.01	NA	<0.01	<0.025
	9/1/1994	Outside Northern Boundary of Warehouse (~21 feet SW of SS2)	SS3	8.3	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.025	NA	<0.01	<0.01	NA	<0.01	<0.025
	9/28/1994	Southern Portion of Concrete Structure Excavation Area	EXC-S	5.0	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.025	NA	<0.01	<0.01	NA	0.59	<0.025
	9/28/1994	Southwest Area of Excavation	EXC-SW	5.0	0.07	<0.02	<0.02	<0.02	<0.02	NA	<0.05	NA	0.05	<0.02	NA	**4.0**	<0.050
	10/7/1994	Under Concrete Structure	UCS-9	10.7	<0.04	<0.04	<0.04	<0.04	<0.04	NA	<0.1	NA	0.23	<0.04	NA	**4.4**	<0.100
	10/11/1994	Inside the Concrete Structure	ICS-BP-21	IN[(7)]	**60**	<18	<18	<18	<18	NA	<45.0	NA	**420**	<18	NA	**16000[(D1)]**	<45.0
	10/7/1994	Under Solution Vessel	USV-11	5.5	**1.2**	<1.0	<1.0	<1.0	<1.0	NA	<2.5	NA	**5.1**	<1.0	NA	**73**	<2.50
	11/21/1994	Under Solution Vessel	USV-2-24	6.5	**3.4**	<1.500	<1.500	<1.500	<1.500	NA	<1.500	NA	**9.5**	<1.500	NA	**200[(D2)]**	<1.500
	10/7/1994	Under Pipeline Between Concrete Structure and Sump	UPL-10	9.5	0.04	<0.04	<0.04	<0.04	<0.04	NA	<0.100	NA	0.04	0.22	NA	**4.3**	<0.100
	11/21/1994	Under Pipeline Between Concrete Structure and Sump	UPL-2-23	10.4	<0.100	<0.100	<0.100	<0.100	<0.100	NA	<0.100	NA	<0.100	<0.100	NA	0.1	<0.100
	10/7/1994	East of Sump	EOS-12	2.5	0.04	<0.04	<0.04	<0.04	<0.04	NA	<0.100	NA	0.09	<0.04	NA	**4.8**	<0.100
	10/26/1994	Under Sump	US-22	6.0	<0.025	<0.025	<0.025	<0.025	<0.025	NA	<0.025	NA	0.062	<0.025	NA	0.059	<0.025
	4/22/2003	Drywell 1	DW-1	15 [(2)]	<0.05	<0.05	<0.05	<0.05	<0.05	NA	<0.250	<0.05	<0.05	NA	NA	<0.05	<0.250

Notes:

[a]Soil Samples collected by Scott, Allard & Bohannan (SA&B), unless otherwise noted.

[(1)] Sample locations shown in Figure 4

[(2)] Approximate sample depth of sediment collected inside drywells #1 through #4.

[(3)] 1,2-DCE (Total) includes cis- and trans- isomers

[(4)] ADEQ Residential SRL Standard A.A.C. R18-7-210 Appendix A adopted May 5, 2007 10^{-6} risk level or non-carcinogen value if 10^{-6} risk not provided

[(5)]The Arizona Minimum Groundwater Protection Levels (ADEQ, September 1996)

[(6)] USEPA Residential and Industrial RSL Standard November 2011 (February 2012 IRIS document for PCE).

[(7)] Soil sampled from inside of concrete structure on 10/11/1994

[(D1)] Dilution factor of 1,800 used

[(D2)] Dilution factor of 60 used

[(D3)] Dilution factor of 50 used

[(D4)] Dilution factor of 10 used

NA = Not analyzed

NE - Not established

bgs = below ground surface

< = Constituent not detected at or above method reporting limit

mg/kg = milligrams per kilogram

mg/L = milligrams per liter

TCA - Trichloroethane

TCE - Trichloroethene

DCA - Dichloroethane

DCE - Dichloroethene

PCE - Tetrachloroethene

Bold - Reported amount exceeds applicable standards

Bold - Reported amount exceeds ADEQ GPLs only

Bold - Reported amount exceeds ADEQ Residential SRLs

Bold = Reported amount exceeds ADEQ Residential and Non-residential SRLs (Non-res SRLs)

Highlight = The area including this sample was excavated and should be excluded from HHRA calculations

Highlight = Reported amount exceeds USEPA Regional Screening Levels Residential Soils

Highlight = Reported amount exceeds USEPA Regional Screening Levels Industrial Soils

A.A.C. = Arizona Administrative Code

ADEQ = Arizona Department of Environmental Quality

USEPA = United States Environmental Protection Agency

Table 1 Summary of Historic Soil Sample Analytical Results M52 Constituents of Concern[a]
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Location	Date	Sample Location [1]	Sample Designation	Depth [2] (feet bgs)	1,1,1-TCA	1,1,2-TCA	1,1-DCA	1,2-DCA	1,1-DCE	1,4-Dioxane	Chloroethane	cis-1,2-DCE	PCE	1,2- DCE (Total)[3]	trans-1,2-DCE	TCE	Vinyl chloride
	TCLP Regulatory Levels (mg/L)				NE	NE	NE	0.5	0.7	NE	NE	NE	0.7	NE	NE	0.5	0.2
					USEPA Method 8010 & 1311 Toxicity Characteristic Leachate Procedure (TCLP) (mg/L)												
Northern	11/8/1989	SW of Concrete Tank Structure	R1-1-1A	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	SW of Concrete Tank Structure	R1-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/9/1989	NE concrete Tank Structure	R1-1-2B	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	SW Concrete Tank Structure	R1-1-3A	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	East of Gasoline Underground Storage Tanks	R3-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/11/1991	MW-4	MW4-10'	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/13/1991		MW-4-38'	38	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse	SS1	8.3	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA	<0.0005	NA	<0.0002	<0.0002	NA	<0.0002	<0.0005
	8/31/1994	Outside Northern Boundary of Warehouse (~27 feet SW of SS1)	SS2	7.3	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA	<0.0005	NA	<0.0002	<0.0002	NA	<0.0002	<0.0005
	9/1/1994	Outside Northern Boundary of Warehouse (~21 feet SW of SS2)	SS3	8.3	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA	<0.0005	NA	<0.0002	<0.0002	NA	<0.0002	<0.0005
	9/28/1994	Southern Portion of Concrete Structure Excavation Area	EXC-S	5.0	0.0025	0.13	<0.002	<0.002	<0.002	NA	<0.002	NA	0.0024	<0.002	NA	<0.002	<0.002
	9/28/1994	Southwest Area of Excavation	EXC-SW	5.0	<0.002	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	<0.002	<0.002	NA	<0.002	<0.002
	10/7/1994	Under Concrete Structure	UCS-9	10.7	<0.002	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	0.0055	0.012	NA	0.31	<0.002
	10/11/1994	Inside the Concrete Structure	ICS-BP-21	IN[7]	0.16	0.064	<0.01	<0.01	<0.01	NA	<0.01	NA	0.58	<0.01	NA	**50[(D3)]**	<0.01
	10/7/1994	Under Solution Vessel	USV-11	5.5	0.1	<0.01	<0.01	<0.01	<0.01	NA	<0.01	NA	0.058	<0.01	NA	**1.9[(D3)]**	<0.01
	11/21/1994	Under Solution Vessel	USV-2-24	6.5	0.027	<0.005	<0.005	<0.005	<0.005	NA	<0.005	NA	0.022	<0.005	NA	**1.10**	<0.005
	10/7/1994	Under Pipeline Between Concrete Structure and Sump	UPL-10	9.5	0.022	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	0.049	<0.002	NA	**1.5[(D4)]**	<0.002
	11/21/1994	Under Pipeline Between Concrete Structure and Sump	UPL-2-23	10.4	<0.005	<0.005	<0.005	<0.005	<0.005	NA	<0.005	NA	<0.005	<0.005	NA	<0.005	<0.005
	10/26/1994	Under Sump	US-22	6.0	<0.002	<0.002	<0.002	<0.002	<0.002	NA	<0.002	NA	<0.002	<0.002	NA	<0.002	<0.002
	4/22/2003	DW-1	DW-1	15 [2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

[a]Soil Samples collected by Scott, Allard & Bohannan (SA&B), unless otherwise noted.

[1] Sample locations shown in Figure 4

[2] Approximate sample depth of sediment collected inside drywells #1 through #4.

[3] 1,2-DCE (Total) includes cis- and trans- isomers

[4] ADEQ Residential SRL Standard A.A.C. R18-7-210 Appendix A adopted May 5, 2007 10^{-6} risk level or non-carcinogen value if 10^{-6} risk not provided

[5]The Arizona Minimum Groundwater Protection Levels (ADEQ, September 1996)

[6] USEPA Residential and Industrial RSL Standard November 2011 (February 2012 IRIS document for PCE).

[7] Soil sampled from inside of concrete structure on 10/11/1994

[(D1)] Dilution factor of 1,800 used

[(D2)] Dilution factor of 60 used

[(D3)] Dilution factor of 50 used

[(D4)] Dilution factor of 10 used

NA = Not analyzed

NE - Not established

bgs = below ground surface

< = Constituent not detected at or above method reporting limit

mg/kg = milligrams per kilogram

mg/L = milligrams per liter

TCA - Trichloroethane

TCE - Trichloroethene

DCA - Dichloroethane

DCE - Dichloroethene

PCE - Tetrachloroethene

Bold - Reported amount exceeds applicable standards

Bold - Reported amount exceeds ADEQ GPLs only

Bold - Reported amount exceeds ADEQ Residential SRLs

Bold = Reported amount exceeds ADEQ Residential and Non-residential SRLs (Non-res SRLs)

Highlight = The area including this sample was excavated and should be excluded from HHRA calculations

Highlight = Reported amount exceeds USEPA Regional Screening Levels Residential Soils

Highlight = Reported amount exceeds USEPA Regional Screening Levels Industrial Soils

A.A.C. = Arizona Administrative Code

ADEQ = Arizona Department of Environmental Quality

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Table 2 Motorola 52nd Street Superfund Site Constituents of Concern Detected in Soil Vapor Samples
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Contaminants of Concern (mg/m^3)												Leak Tracer Tests (mg/m3)	
Sample Description	Sample Location	Potential Source Area	Sample ID	Parent Sample	Sample Depth (feet bgs)	1,1,1-TCA	1,1,2-TCA	1,1-DCA	1,2-DCA	1,1-DCE	1,4-Dioxane	Chloroethane	cis-1,2-DCE	PCE	trans-1,2-DCE	TCE	Vinyl chloride	Butane	IPA
* Calculated Residential Soil Vapor Screening Level						520	0.015	0.15	0.0094	21	0.032	1,000	NE	0.936	6.3	0.043	0.016	NE	730
*Calculated Industrial Soil Vapor Screening Level						2,200	0.077	0.77	0.047	88	0.16	4,400	NE	4.72	26	0.3	0.28	NE	3,100
Northern Portion	Soil Vapor	AdobeAir Warehouse - Inside (northwest corner) sampled 6/2/1993 and 6/3/1993 (SA&B)	SG-1-10'		10	160	NA	**14**	NA	15	NA	NA	NA	**35**	5[1]	**3400**	NA	NA	NA
			SG-2-10'		10	85	NA	**13**	NA	11	NA	NA	NA	**6**	3[1]	**130**	NA	NA	NA
			SG-3-9'		9	150	NA	**23**	NA	2	NA	NA	NA	**96**	18[1]	**11000**	NA	NA	NA
			SG-4-9.5'		9.5	45	NA	**14**	NA	7	NA	NA	NA	**19**	8[1]	**1000**	NA	NA	NA
			SG-5-10'		10	14	NA	<69	NA	4	NA	NA	NA	**7**	<26[1]	**300**	NA	NA	NA
			SG-6-10'		10	10	NA	<69	NA	2	NA	NA	NA	**3**	<26[1]	**170**	NA	NA	NA
			SG-7-2'		2	0.1	NA	<0.3	NA	<0.009	NA	NA	NA	0.02	<0.1[1]	**1**	NA	NA	NA
			SG-7-10'		10	2	NA	<7	NA	0.4	NA	NA	NA	0.5	<3[1]	**25**	NA	NA	NA
			SG-8-7.5'		7.5	2	NA	<5	NA	<0.2	NA	NA	NA	0.2	<2[1]	**31**	NA	NA	NA
			SG-9-2'		2	0.003	NA	<0.3	NA	<0.009	NA	NA	NA	<0.001	<0.1[1]	**0.01**	NA	NA	NA
			SG-9-9.5'		9.5	2	NA	<5	NA	<0.5	NA	NA	NA	0.4	<2[1]	**12**	NA	NA	NA
			SG-10-2'		2	0.005	NA	<0.5	NA	<0.02	NA	NA	NA	<0.003	<0.2[1]	**0.04**	NA	NA	NA
			SG-10-10'		10	0.7	NA	<7	NA	0.2	NA	NA	NA	0.2	<3[1]	**6**	NA	NA	NA
			SG-11-7'		7	3	NA	<7	NA	<0.2	NA	NA	NA	0.6	<3[1]	**64**	NA	NA	NA
			SG-12-7'		7	1	NA	<7	NA	4	NA	NA	NA	0.7	<3[1]	**15**	NA	NA	NA
		AdobeAir Warehouse - Inside (northwest corner) - Phase I Soil Gas Investigation	SG01-(13.3)-092106		13.3	35 D2 J	< .28	NA	**1.2 J**	2.6 D2	< 1.8	< .13	0.23 D2	**3.8 D2**	< .2	**25 D2**	< .13	2.38 T4	< .25
			FD01-092106	SG01-(13.3)-092106	13.3	46 D2 J	< .55	NA	< .41 UJ	2.7 D2	< 3.7	< .27	< .4	**4.7 D2**	< .4	**29 D2**	< .26	7.61 T4	< .5
			SG02-(13.2)-092006		13.2	14 D2	**0.061**	**0.33 D2**	< .041	0.64 D2	< .37	< .027	0.088	**1.5 D2**	< .04	**14 D2**	< .026	NA	0.9 D2
			SG03A-(12.4)-092006		12.4	9.4 D2	< .055	0.14	< .041	0.48	< .37	< .027	< .04	0.55 D2	< .04	**19 D2**	< .026	NA	0.7 D2
			SG04-(13.0)-092106		13	3.8 D2	< .28	< .21	< .21	0.48 D2	< 1.8	< .13	< .2	0.76 D2	< .2	**16 D2**	< .13	1.95 T4	< .25
			SG05A-(14.5)-092106		14.5	1.8 D2	< .28	< .21	< .21	0.23 D2	< 1.8	< .13	< .2	0.69 D2	< .2	**15 D2**	< .13	1.26 T4	< .25
			SG06A-(14.5)-092206		14.5	0.14	< .014	< .01	< .01	0.035	< .092	< .0067	< .01	0.032	< .01	**0.53 D2**	< .0065	<0.01	0.16 D2
			SG07-(14.0)-092206		14	0.72 D2	< .14	< .1	< .1	< .1	< .92	< .067	< .1	0.57 D2	< .1	**13 D2**	< .065	<0.12	0.3 D2
			SG08-(14.5)-092206		14.5	0.22	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.16	< .04	**2.7 D2**	< .026	<0.05	0.22 D2
			SG09-(14.5)-092206		14.5	0.072	< .028	< .021	< .021	< .02	< .18	< .013	< .02	0.069	< .02	**0.88 D2**	< .013	<0.02	0.3 D2
			SG10-(13.0)-092006		13	4.3 D2	< .055	0.095	< .041	0.26 D2	< .37	< .027	< .04	0.45 D2	< .04	**4 D2**	< .026	NA	< .05
			SG11A-(15.0)-092506		15	1.5 D2	< .028	0.031	< .021	0.064	< .18	< .013	< .02	0.083	< .02	**1.2 D2**	< .013	<0.02	< .025
			SG12-(14.7)-09192006P1		14.7	1 D2	< .055	< .041	< .041	0.048	< .37	< .027	< .04	0.1	< .04	**2.5 D2**	< .026	NA	< .05
			SG12-(14.7)-09192006P3		14.7	0.94	< .055	< .041	< .041	0.044	< .37	< .027	< .04	0.1	< .04	**2.4**	< .026	NA	< .05
			SG12-(14.7)-09192006P7		14.7	1 D2	< .055	< .041	< .041	0.048	< .37	< .027	< .04	0.11	< .04	**2.5 D2**	< .026	NA	< .05
		Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG13-(13.2)-092106		13.2	1.5 D2	< .28	< .21	< .21	< .2	< 1.8	< .13	< .2	0.69 D2	< .2	**14 D2**	< .13	1.19 T4	< .25
			SG14-(14.4)-092106		14.4	1.7 D2	< .28	< .21	< .21	< .2	< 1.8	< .13	< .2	**1 D2**	< .2	**20 D2**	< .13	1.26 T4	< .25
			SG15-(14.8)-092206		14.8	0.45 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.42 D2	< .04	**2.9 D2**	< .026	<0.05	< .05
			FD01-092206	SG15-(14.8)-092206	14.8	0.5 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.48 D2	< .04	**3.3 D2**	< .026	<0.05	< .05
			SG16-(15.0)-092206		15	0.66 D2	< .14	< .1	< .1	< .1	< .92	< .067	< .1	0.61 D2	< .1	**9.4 D2**	< .065	<0.05	0.23 D2
			SG17-(14.7)-092206		14.7	0.28 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.26	< .04	**4 D2**	< .026	<0.05	0.082
			FD02-092206	SG17-(14.7)-092206	14.7	0.25	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.26	< .04	**3.7 D2**	< .026	<0.05	< .05
			SG18-(14.5)-092206		14.5	0.22	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.21	< .04	**2.6 D2**	< .026	<0.05	0.11
			SG19-(11.9)-092106		11.9	0.77 D2	< .055	< .041	< .041	0.048	< .37	< .027	< .04	0.19	< .04	**3.9 D2**	< .026	<0.05	< .05
			SG20-(12.4)-092106		12.4	0.83 D2	< .14	< .1	< .1	< .1	< .92	< .067	< .1	0.44 D2	< .1	**6.6 D2**	< .065	1 T4	2.3 D2
			SG21-(15.0)-092106		15	0.88 D2	< .14	< .1	< .1	< .1	< .92	< .067	< .1	0.59 D2	< .1	**9.4 D2**	< .065	0.45 T4	< .12
			SG22-(15.2)-092206		15.2	0.61 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.5 D2	< .04	**4.6 D2**	< .026	<0.05	< .05
			SG23-(14.5)-092206		14.5	0.31 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.19	< .04	**2.7 D2**	< .026	<0.05	0.17 D2
			SG24-(14.5)-092206		14.5	0.28	< .028	< .021	< .021	0.022	< .18	< .013	< .02	0.2	< .02	**3.2 D2**	< .013	<0.05	0.087
			SG25-(14.4)-092206		14.4	0.24	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.21	< .04	**2.6 D2**	< .026	<0.05	0.08
			SG26-(15.0)-092106		15	0.46 D2	< .055	< .041	< .041	0.044	< .37	< .027	< .04	0.28	< .04	**3.3 D2**	< .026	0.20 T4	< .05
			SG27-(14.8)-092206		14.8	0.29 D2	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.14	< .04	**1.3 D2**	< .026	<0.05	< .05
			SG28-(14.2)-092206		14.2	0.23	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.13	< .04	**1.3 D2**	< .026	<0.05	0.077
			SG29-(14.1)-092206		14.1	0.17	< .014	< .01	< .01	0.017	< .092	< .0067	< .01	0.083	< .01	**0.94 D2**	< .0065	0.24 T4	0.23 D2
			SG30-(14.5)-092506		14.5	0.2	< .028	< .021	< .021	0.022	< .18	< .013	< .02	0.11	< .02	**1.4 D2**	< .013	<0.02	0.052
			SG31-(14.5)-092206		14.5	0.23	< .028	< .021	< .021	< .02	< .18	< .013	< .02	0.083	< .02	**0.77 D2**	< .013	<0.02	0.18 D2
			SG32-(14.0)-092206		14	0.18	< .028	< .021	< .021	< .02	< .18	< .013	< .02	0.076	< .02	**0.72 D2**	< .013	<0.02	0.3 D2
			SG33-(13.0)-092506		13	0.14	< .014	< .01	< .01	0.016	< .092	< .0067	< .01	0.09	< .01	**0.77 D2**	< .0065	0.06 T4	< .012
			SG34-(14.1)-092506		14.1	0.072	< .0055	< .0041	< .0041	0.0052	< .037	< .0027	< .004	0.043	< .004	**0.29 D2**	< .0026	<0.005	< .005
		AdobeAir Warehouse - Inside (northwest corner) - Phase II Soil Gas Investigation	SG65-(11)-12102007		11	0.14	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .21	< .02	**1.4 D2**	< .013	NA	< .05
			SG66-(12)-12102007		12	0.12	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .34	< .02	**1.4 D2**	< .013	NA	< .05
			SG67-(11)-12102007		11	0.088	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .23	< .02	**1.5 D2**	< .013	NA	< .05
			SG68-(11)-12102007		11	0.061	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .23	< .02	**1.3 D2**	< .013	NA	< .05
			DUP01-(11)-12102007	SG68-(11)-12102007	11	0.072	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .23	< .02	**1.4 D2**	< .013	NA	< .05
			SG70-(12)-12102007		12	0.12	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .26	< .02	**2.2 D2**	< .013	NA	< .05
			SG71-(12)-12102007		12	0.27	< .028	< .021	< .021	0.021	< .18	< .013	< .02	< .42	< .02	**5.4 D2**	< .013	NA	< .05
			SG72-(10)-12102007		10	0.16	< .028	< .021	< .021	< .02	< .18	< .013	< .02	< .33	< .02	**2.3**	< .013	NA	< .05
			SG73-(10.5)-12112007		10.5	0.38 D2	< .028	< .021	< .021	0.031	< .18	< .013	< .02	< .48	< .02	**13 D2**	< .013	NA	< .05
			SG74-(10)-12112007		10	0.88	< .028	< .021	< .021	0.1	< .18	< .013	< .02	< .69	< .02	**10 D2**	< .013	<0.02 T4	< .05
			SG75-(12)-12112007		12	0.83 D2	< .028	0.023	< .021	0.097	< .18	< .013	< .02	< .76	< .02	**8.3 D2**	< .013	NA	< .05

Notes

All units are in mg/m^3 (milligrams per cubic meter)
bgs - below ground surface
TCA - Trichloroethane
DCA - Dichloroethane
DCE - Dichloroethene
PCE - Tetrachloroethene
TCE - Trichloroethene
IPA - Isopropyl Alcohol
NE - Not Established
SG - Soil Gas
NA - Not Analyzed
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
< - Constituent not detected at or above method reporting limit.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for Residential use Only.
D2 - Sample diluted

J - Poor field duplicate precision
T4 - Tentatively identified compound. Concentration is estimated and based on the closest internal standards.
FD - Field Duplicate
UJ - Result reported below the reporting limit, correlates to the E4 flag issued by laboratory
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test
UB - Compound considered non-detect at the listed value due to associated blank contamination.
E8 - Analyte reported to the method detection limit (MDL) per project specifications.
Target analyte was not detected in sample.
E4 - Concentration estimated. Analyte detected below laboratory minimum reporting level (MRL)
V2 - Indicates the second attempt for purge volume test event for the same borehole.
-- = Not Applicable
AA - Ambient Air
TB - Trip Blank
U - Analyte detected in ambient air sample or trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011 [February 2012 IRIS document for PCE]) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - Samples were reported as a whole for 1,2-Dichloroethylene (cis- and trans-1,2-DCE combined).
2 - Samples collected from the vapor monitoring wells have periodically been mislabeled at various times since they were installed. For the initial sampling for VMW-1 (January 2008), the samples were labeled as VW instead of VMW. Also, the depths for the screened interval have also been periodically mislabeled.
The actual depths are as follows: VMW-01 (12.5', 40', 55', and 79.5' bgs), VMW-02 (10', 40', 55', and 79' bgs), VMW-03 (8', 35', 52', and 73' bgs), and VMW-04 (13', 50.5', and 75').
3 - Samples also used for the Soil Vapor Extraction Baseline Soil Vapor Sampling Event.
4 - Ambient Air sample can only be used to evaluate SG-54 through SG-56
5 - Ambient Air sample can only be used to evaluate SG-1 through SG-34
6 - Ambient Air sample can only be used to evaluate SG-57 through SG-60
7 - Ambient Air sample can only be used to evaluate SG-61 through SG-63
8 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table 2 Motorola 52nd Street Superfund Site Constituents of Concern Detected in Soil Vapor Samples
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Contaminants of Concern (mg/m³)												Leak Tracer Tests (mg/m3)	
Sample Description	Sample Location	Potential Source Area	Sample ID	Parent Sample	Sample Depth (feet bgs)	1,1,1-TCA	1,1,2-TCA	1,1-DCA	1,2-DCA	1,1-DCE	1,4-Dioxane	Chloroethane	cis-1,2-DCE	PCE	trans-1,2-DCE	TCE	Vinyl chloride	Butane	IPA
* Calculated Residential Soil Vapor Screening Level						520	0.015	0.15	0.0094	21	0.032	1,000	NE	0.936	6.3	0.043	0.016	NE	730
*Calculated Industrial Soil Vapor Screening Level						2,200	0.077	0.77	0.047	88	0.16	4,400	NE	4.72	26	0.3	0.28	NE	3,100
Northern Portion	Soil Vapor	AdobeAir Warehouse - Inside (northwest corner) - Phase I Soil Gas Investigation	SG76-(10)-12112007		10	1.8 D2	< .055	0.041	< .041	0.21 D2	< .37	< .027	< .04	< .83	< .04	**12 D2**	< .026	NA	< .1
		Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG77-(11)-12112007		11	4.5 D2	< .055	0.087	< .041	0.52 D2	< .37	< .027	< .04	< .9	< .04	**17 D2**	< .026	NA	< .1
			SG78-(10.5)-12112007		10.5	4.4	< .055	0.091	< .041	0.6	< .37	< .027	< .04	< 1.3	< .04	**12 D2**	< .026	<0.02 T4	< .1
			DUP01-(10.5)-12112007	SG78-(10.5)-12112007	10.5	3.4 D2	< .055	0.07	< .041	0.44 D2	< .37	< .027	< .04	< 1.1	< .04	**11 D2**	< .026	NA	< .1
			SG79-(12.5)-12052007		12.5	0.36 D2	< .055	< .041	< .041	0.06	< .37	< .027	< .04	0.76 D2	< .04	**5.5 D2**	< .026	NA	< .1
			SG80-(9.5)-12112007		9.5	15 D2	< .055	**0.22 D2**	< .041	1.5 D2	< .37	< .027	< .04	< 1.5	< .04	**20 D2**	< .026	NA	< .1
			SG81-(11)-12112007		11	27 D2	**0.13**	**0.82 D2**	< .041	3.7 D2	< .37	< .027	0.11	**3.3 D2**	< .04	**22 D2**	< .026	NA	< .1
			SG82-(10)-12112007		10	7.2 D2	< .055	**0.17**	< .041	0.93 D2	< .37	< .027	< .04	**1.7 D2**	< .04	**14 D2**	< .026	NA	< .1
			SG83-(10)-12052007		10	0.2	< .055	< .041	< .041	0.048	< .37	< .027	< .04	0.49 D2	< .04	**5.1 D2**	< .026	NA	< .1
			SG84-(10)-12112007		10	20 D2	**0.14**	**0.7 D2**	< .041	2.5 D2	< .37	< .027	0.12	**2.6 D2**	< .04	**17 D2**	< .026	NA	< .1
			SG85-(10)-12112007		10	12 D2	**0.12**	**0.31 D2**	< .041	1.2 D2	< .37	< .027	< .04	< 1.4	< .04	**9.4 D2**	< .026	NA	< .1
			SG86-(10)-12112007		10	4.8 D2	< .055	**0.19**	< .041	0.6 D2	< .37	< .027	< .04	< 1.6	< .04	**9.4 D2**	< .026	<0.02 T4	< .1
			SG87-(12)-12052007		12	< .055	< .055	< .041	< .041	< .04	< .37	< .027	< .04	0.16	< .04	**1.4 D2**	< .026	NA	< .1
	AdobeAir Warehouse - Outside (Northwest) - Phase II & III Soil Gas Investigation		SG90-(15)-12042007		15	0.33 D2	< .028	< .021	< .021	0.064	< .18	< .013	< .02	0.14	< .02	**1.4 D2**	< .013	NA	< .05
			DUP01-(15)-12042007	SG90-(15)-12042007	15	0.5 D2	< .028	< .021	< .021	0.089	< .18	< .013	< .02	0.21	< .02	**1.9 D2**	< .013	NA	< .05
			SG91-(15)-12112007		15	0.11	< .014	< .01	< .01	0.019	< .092	< .0067	< .01	< .076	< .01	**0.88 D2**	< .0065	NA	< .025
			SG92-(15)-12112007		15	< .055	< .055	< .041	< .041	0.056	< .37	< .027	< .04	< .18	< .04	**4.2 D2**	< .026	NA	< .1
			SG-97-14.5-090908		14.5	< .0535	< .0535	0.049	< .0397	0.091	NA	< .0259	< .0389	0.24	< .0389	**5.1**	< .0251	NA	< .0959
			SG-98-12-090908		12	< .0546	< .0546	< .0405	< .0405	< .0396	NA	< .0264	< .0396	< .0678	< .0396	**0.97**	< .0256	NA	< .0983
			DUP-090908	SG-98-12-090908	12	< .0546	< .0546	< .0405	< .0405	< .0396	NA	< .0264	< .0396	< .0678	< .0396	**0.64 J**	< .0256	NA	< .0983
			SG-99-11-090908		11	1.8	< .0546	< .0405	< .0405	0.087	NA	< .0264	< .0396	0.34	< .0396	**1.7**	< .0256	NA	< .101
			SG-100-10-090908		10	0.071	< .00546	< .00405	< .00405	< .00396	NA	< .00264	< .00396	0.046	< .00396	**0.11**	< .00256	NA	0.044
	AdobeAir Warehouse-Outside (Northeast)		SG-101-15-090908		15	< .0529	< .0529	< .0393	< .0393	< .0385	NA	< .0256	< .0385	0.075	< .0385	**0.4**	< .0248	NA	< .0959
			SG-102-15-090908		15	< .0136	< .0136	< .0101	< .0101	< .00991	NA	< .0066	< .00991	0.046	< .00991	**0.53**	< .00639	NA	< .0246
	AdobeAir Warehouse - Outside (west)	Dry Well (R4-5)	SG50-(10.0)-092506		10	0.088	< .055	0.045	< .041	0.081	< .37	< .027	< .04	0.15	< .04	**4.1 D2**	< .026	<0.05	< .05
			SG93-(10)-12112007		10	0.048	< .014	< .01	< .01	< .01	< .092	< .0067	< .01	< .055	< .01	**0.61 D2**	< .0065	NA	< .025
			SG94-(15)-12052007		15	< .055	< .055	0.045	< .041	0.052	< .37	< .027	< .04	0.11	< .04	**2.3 D2**	< .026	NA	< .1
			SG-95-10-090908		10	< .054	< .054	0.057	< .0401	< .0393	NA	< .0261	< .0393	< .0671	< .0393	**0.46**	< .0253	NA	< .0983
			SG-96-10-090908		10	< .0546	< .0546	0.093	< .0405	0.12	NA	< .0264	< .0396	0.24	< .0396	**7 J**	< .0256	NA	< .101
	AdobeAir Warehouse - Inside (west)		SG88-(12.5)-12052007		12.5	0.083	< .028	0.025	< .021	0.037	< .18	< .013	< .02	0.25	< .02	**3.2 D2**	< .013	NA	< .05
			SG89-(15)-12052007		15	0.033	< .014	0.011	< .01	0.017	< .092	< .0067	< .01	0.1	< .01	**0.94**	< .0065	NA	0.027
	AdobeAir Warehouse - Inside (northwest corner) - Semi Annual Vapor Sampling from Vapor Monitoring Well VMW-01	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	VMW-01(12.5)-1-03172008		12.5	9.4 D2	**0.11**	**0.29 D2**	< .041	0.81 D2	< .37	< .027	< .04	0.76 D2	< .04	**7.2 D2**	< .026	< 0.002	< .1
			VMW-01(12.5)-3-03172008		12.5	5.5 D2	**0.077**	**0.19**	< .041	0.48 D2	< .37	< .027	< .04	0.56 D2	< .04	**5.3 D2**	< .026	< 0.002	< .1
			VMW-01(12.5)-7-03172008		12.5	11 D2	**0.12**	**0.33 D2**	< .041	0.93 D2	< .37	< .027	< .04	**0.97 D2**	< .04	**8.3 D2**	< .026	< 0.002	< .1
			VW-01(12.5)-01212008 [2]		12.5	7.7 D2	**0.1**	**0.29 D2**	< .041	0.97 D2	< .37	< .027	< .04	**1.4 D2**	< .04	**7.7 D2**	< .026	NA	< .05
			VMW-01(12.5)091008 [3]		12.5	31	**0.19**	**0.65**	< .101	2.1	NA	< .066	< .0991	**3.7**	< .0991	**19**	< .0639	< 59.4 T4	< .246
			VMW01(12.5)03192009		12.5	5.5	< .273	< .202	< .202	0.52	< .901	< .132	< .198	0.38	< .198	**3.6**	< .128	< .238	3
			VMW-01(12.5)-091009		12.5	6.6	< .136	**0.22**	< .101	0.71	< .18	< .066	< .0991	**1.2**	< .0991	**6.4**	< .0639	NA	< .246
			VMW-01-(12.5)-03172010		12.5	7.1	**0.15**	**0.19**	< .00202	0.75	< .00901	< .00132	0.056	**1.4**	0.002	**7**	< .00128	< 0.002	< .00492
			VMW-01(12.5)-09092010		12.5	16	**0.087**	**0.22**	< .002	0.91	< .009	< .0013	0.052	**1.4**	0.0022	**9.1**	< .0013	< 0.002	< .0049
			VMW-01(40)-033108		40	3.7	< .28	**0.23 D2**	< .21	0.69 D2	< 1.8	< .13	0.96 D2	**6.1 D2**	< .2	**17 D2**	< .13	NA	< .5
			VMW-01(45)091008 [3]		40 [2]	2.7	< .273	**0.22**	< .202	0.44	NA	< .132	< .198	0.52	< .198	**9.1**	< .128	< 119 T4	< .492
			VW-01(40)-01212008		40	2.2 D2	< .055	**0.2**	< .041	0.48 D2	< .37	< .027	0.052	0.49 D2	< .04	**6.1 D2**	< .026	NA	< .05
			VMW01(40)03192009		40	0.6	< .273	< .202	< .202	< .198	< .901	< .132	< .198	0.35	< .198	**3.1**	< .128	< .238	4.9
			VMW-01(40)-091009		40	0.066	< .054	< .0401	< .0401	0.04	< .177	< .0261	< .0393	< .0671	< .0393	**0.7**	< .0253	NA	< .0959
			VMW-01-(40)-03172010		40	0.66	**0.043**	**0.18**	< .00202	0.25	< .00901	< .00132	0.14	0.56	0.0044	**9.1**	< .00128	< 0.002	0.1
			VMW-01(40)-09092010		40	0.82 UB	< .042	**0.18**	< .031	0.33	< .14	< .02	0.11	0.43	< .031	**6.5**	< .02	< 0.002	< .076
			VMW-01(55)-033108		55	4.5	< .28	**0.31**	< .21	0.56	< 1.8	< .13	< .2	0.83	< .2	**14**	< .13	< 0.002	< .5
			VMW-01(55)091008 [3]		55	1.9	< .273	**0.35**	< .202	0.44	NA	< .132	< .198	**1**	< .198	**16**	< .128	< 119 T4	< .492
			VW-01(55)-01212008		55	1 D2	< .055	**0.16**	< .041	0.33 D2	< .37	< .027	0.064	0.4 D2	< .04	**7.2 D2**	< .026	NA	< .05
			VMW01(55)03192009		55	3.5	< .273	**0.25**	< .202	0.25	< .901	< .132	< .198	0.62	< .198	**9.7**	< .128	< .238	7.4
			DUP-03192009	VMW01(55)03192009	55	< .273	< .273	< .202	< .202	0.36	< .901	< .132	< .198	0.54	< .198	**8.6**	< .128	< .238	3.9
			VMW-01(55)-091009		55	0.93	< .273	**0.24**	< .202	0.31	< .177	< .132	< .198	**2**	< .198	**11**	< .128	NA	< .492
			VMW-01-(55)-03172010		55	3.9	**0.053**	**0.28**	< .00202	0.21	< .00901	< .00132	0.16	**1**	0.0048	**12**	< .00128	T4	< .00492
			VMW-01(55)-09092010		55	0.29 UB	< .041	**0.24**	< .03	0.23	< .14	< .02	0.13	0.43	< .03	**6.5**	< .019	< 0.002	< .074
			DUP-09092010	VMW-01(55)-09092010	55	0.22 UB	< .04	**0.18**	< .03	0.18	< .13	< .02	0.099	0.33	< .029	**7**	< .019	< 0.002	< .074
			VMW-01(79.5)-033108		79.5	0.77	< .28	**0.27**	< .21	0.44	< 1.8	< .13	0.39	4.4	< .2	**18**	< .13	< 0.002	< .5
			VMW-01(79.5)091008 [3]		79.5	0.28	< .273	**0.31**	< .202	0.3	NA	< .132	< .198	0.58	< .198	**13**	< .128	< 119 T4	< .492
			DUP-091008 [3]	VMW-01(79.5)091008	79.5	< .273	< .273	**0.29**	< .202	0.37	NA	< .132	< .198	0.43	< .198	**11**	< .128	< 119 T4	< .492
			VW-01(79.5)-01212008		79.5	0.36 D2	< .055	**0.19**	< .041	0.27 D2	< .37	< .027	0.096	0.39	< .04	**8.8 D2**	< .026	NA	< .05
			DUP-01212008	VW-01(79.5)-01212008	79.5	0.43 D2	< .055	**0.23 D2**	< .041	0.33 D2	< .37	< .027	0.12	0.45 D2	< .04	**12 D2**	< .026	NA	< .05
			VMW-01(79.5)-091009		79.5	< .3	< .3	< .223	< .223	0.27	< .198	< .145	< .218	**1.1**	< .218	**8.1**	< .141	NA	< .541
			DUP-091009	VMW-01(79.5)-091009	79.5	< .273	< .273	< .202	< .202	0.26	< .18	< .132	< .198	0.88	< .198	**7**	< .128	NA	< .492
			VMW-01-(79.5)-03172010		79.5	0.14	**0.021**	**0.21**	0.0012 J	0.26	0.0065 J	< .00132	0.19	0.49	0.004	**9.7**	< .00128	< 0.002	< .00492
			DUP-03172010	VMW-01-(79.5)-03172010	79.5	0.18	**0.021**	**0.22**	< .00202	0.27	0.005 J	< .00132	0.14	0.58	0.0044	**9.7**	< .00128	< 0.002	< .00492
			VMW01(79.5)03192009		79.5	< .273	< .273	< .202	< .202	0.34	< .901	< .132	< .198	0.38	< .198	**7**	< .128	< .238	3.7

Notes

All units are in mg/m³ (milligrams per cubic meter)
bgs - below ground surface
TCA - Trichloroethane
DCA - Dichloroethane
DCE - Dichloroethene
PCE - Tetrachloroethene
TCE - Trichloroethene
IPA - Isopropyl Alcohol
NE - Not Established
SG - Soil Gas
NA - Not Analyzed
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
< - Constituent not detected at or above method reporting limit.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for Residential use Only.
D2 - Sample diluted

J - Poor field duplicate precision
T4 - Tentatively identified compound. Concentration is estimated and based on the closest internal standards.
FD - Field Duplicate
UJ - Result reported below the reporting limit, correlates to the E4 flag issued by laboratory
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test
UB - Compound considered non-detect at the listed value due to associated blank contamination.
E8 - Analyte reported to the method detection limit (MDL) per project specifications.
Target analyte was not detected in sample.
E4 - Concentration estimated. Analyte detected below laboratory minimum reporting level (MRL)
V2 - Indicates the second attempt for purge volume test event for the same borehole.
-- = Not Applicable
AA - Ambient Air
TB - Trip Blank
U - Analyte detected in ambient air sample or trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011 [February 2012 IRIS document for PCE]) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - Samples were reported as a whole for 1,2-Dichloroethylene (cis- and trans-1,2-DCE combined).
2 - Samples collected from the vapor monitoring wells have periodically been mislabeled at various times since they were installed. For the initial sampling for VMW-1 (January 2008), the samples were labeled as VW instead of VMW. Also, the depths for the screened interval have also been periodically mislabeled. The actual depths are as follows: VMW-01 (12.5', 40', 55', and 79.5' bgs), VMW-02 (10', 40', 55', and 79' bgs), VMW-03 (8', 35', 52', and 73' bgs), and VMW-04 (13', 50.5', and 75').
3 - Samples also used for the Soil Vapor Extraction Baseline Soil Vapor Sampling Event.
4 - Ambient Air sample can only be used to evaluate SG-54 through SG-56
5 - Ambient Air sample can only be used to evaluate SG-1 through SG-34
6 - Ambient Air sample can only be used to evaluate SG-57 through SG-60
7 - Ambient Air sample can only be used to evaluate SG-61 through SG-63
8 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table 2 Motorola 52nd Street Superfund Site Constituents of Concern Detected in Soil Vapor Samples
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Contaminants of Concern (mg/m^3)														Leak Tracer Tests (mg/m3)	
Sample Description		Sample Location	Potential Source Area	Sample ID	Parent Sample	Sample Depth (feet bgs)	1,1,1-TCA	1,1,2-TCA	1,1-DCA	1,2-DCA	1,1-DCE	1,4-Dioxane	Chloroethane	cis-1,2-DCE	PCE	trans-1,2-DCE	TCE	Vinyl chloride	Butane	IPA
* Calculated Residential Soil Vapor Screening Level							520	0.015	0.15	0.0094	21	0.032	1,000	NE	0.936	6.3	0.043	0.016	NE	730
*Calculated Industrial Soil Vapor Screening Level							2,200	0.077	0.77	0.047	88	0.16	4,400	NE	4.72	26	0.3	0.28	NE	3,100
Northern Portion	Soil Vapor	AdobeAir Warehouse - Inside (NW Corner) Soil Vapor Extraction Pilot Test at VMW-01		SVE1VMW-01 (12.5) 091108		12.5	20	**0.21**	**0.53**	< .0401	2.2	NA	< .0261	0.075	**3.2**	< .0393	**15**	< .0253	NA	< .0959
				SVE-CVMW-01(40)091208		40	1.7	**0.055**	**0.3**	< .0405	0.67	NA	< .0264	0.16	**0.95**	< .0396	**9.7**	< .0256	NA	< .0983
				SVE1VMW-01 (40) 091108		40	0.13	< .00546	< .00405	< .00405	0.0056	NA	< .00264	< .00396	0.064	< .00396	**0.19**	< .00256	NA	< .00983
				SVE2VMW-01 (12.5) 091108		12.5	11	**0.098**	**0.25**	< .0405	0.91	NA	< .0264	< .0396	**1.2**	< .0396	**10**	< .0256	NA	< .101
				SVE-CVMW-01(55)091208		55	0.82	**0.055**	**0.27**	< .0405	0.56	NA	< .0264	0.16	0.88	< .0396	**11**	< .0256	NA	< .0983
				SVE2VMW-01 (40) 091108		40	2.1	< .0535	**0.29**	< .0397	0.83	NA	< .0259	0.13	0.75	< .0389	**14**	< .0251	NA	< .0959
		AdobeAir Warehouse - Outside (Northwest) - SVE Pilot Test Baseline, Vapor Monitoring Well Samples		VMW-02(10)-091108 [3]		10	0.32	< .0546	< .0405	< .0405	0.067	NA	< .0264	< .0396	0.14	< .0396	**2.8**	< .0256	< .475	< .0983
				VMW-02(40)091008 [3]		40	0.47	< .054	**0.19**	< .0401	0.56	NA	< .0261	0.071	0.39	< .0393	**12**	< .0253	0.62 T4	< .0983
				VMW-02-(55)-091008 [3]		55	0.34	< .0546	**0.53**	< .0405	0.6	NA	< .0264	0.27	0.54	< .0396	**16**	< .0256	< .475	< .0983
				VMW-02-(80)-091008 [3]		80	0.2	< .054	**0.44**	< .0401	0.56	NA	< .0261	0.33	0.88	< .0393	**12**	< .0253	< .475	< .0983
				DUP2-091008 [3]	VMW-02-(80)-091008	80	0.2	< .0529	**0.44**	< .0393	0.6	NA	< .0256	0.33	0.75	< .0385	**13**	< .0248	< .452	< .0959
				VMW-03-(13)-090908 [3]		13	0.12	< .00546	< .00405	< .00405	0.0067	NA	< .00264	< .00396	0.075	< .00396	**0.34**	< .00256	< .0475	< .00983
				VMW-03-(35)-090908 [3]		35	0.6	< .0546	< .0405	< .0405	0.091	NA	< .0264	< .0396	0.19	< .0396	**1.6**	< .0256	< .475	< .0983
				VMW-03-(55)-090908 [3]		55	0.43	< .0546	< .0405	< .0405	0.15	NA	< .0264	< .0396	0.27	< .0396	**3.8**	< .0256	< .475	< .0983
				VMW-03(80)091908 [3]		80	< .00273	< .00273	< .00202	< .00202	< .00198	NA	< .00132	< .00198	< .00339	< .00198	< .00269	< .00128	< .0238	< .00492
				VMW-04-(13)-091008 [3]		13	0.12	< .0529	0.04	< .0393	0.091	NA	< .0256	< .0385	0.23	< .0385	**4.6**	< .0248	< .452	< .0959
				VMW-04-(50)-091008 [3]		50	< .0535	< .0535	**0.3**	< .0397	0.32	NA	< .0259	0.16	0.23	< .0389	**11**	< .0251	1.8 T4	< .0959
				VMW-04(75)-091108 [3]		75	0.066	< .0546	**0.4**	< .0405	0.38	NA	< .0264	0.24	0.37	< .0396	**16**	< .0256	< .475	< .101
Sitewide [8]	Ambient Air	GranQuartz Building [4]	GranQuartz Building	AA01-092106		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	0.014	< .0013	0.007 T4	0.11
		AdobeAir Building [5]	AdobeAir Building	AA01-(0)-09192006		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	0.0077
		Corsicana Building [6]	Corsicana Building	AA01-092506		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	0.016	< .0013	< 0.002	< .0025
		Fab West Building [7]	Fab West Building	AA02-092506		--	< .0018 E8 UJ	< .0055	< .0041	< .0041	< .004	< .037	< .0027	< .004	< .0025 E8 UJ	< .004	< .0017 E8 UJ	< .0026	< 0.005	0.06
		Outside north of SG-102	AdobeAir Building	AA-IA-AA-02052009		--	< .00202	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	< .00197	< .00198	< .00199	< .00128	NA	NA
		Outside north of SG-102	AdobeAir Building	AA-IA-AA1-082109		--	0.000048 J	< .000027	< .000001	0.000055	< .00002	< 2.5	< .00053	< .0000099	0.0001 J	< .00002	0.000036	< .0000064	NA	NA
		Outside south of SG-41	AdobeAir Building	AA-IA-AA2-082109		--	0.000052 J	< .000027	< .000001	0.000062	< .00002	< 2.5	< .00053	< .0000099	0.00013 J	< .00002	0.000044	< .0000064	NA	NA
	Field Blanks	SG-83	Phase II Soil Gas Investigation	FB01-(0)-12052007		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	0.0096	0.18	< .002	0.042	< .0013	NA	0.0067
		SG-70		FB01-(0)-12102007		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	0.0025	0.083	< .002	0.011	< .0013	NA	< .005
		SG-78		FB01-(0)-12112007		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	0.055	< .002	< .0028	< .0013	NA	0.0052
		SG-98	Phase III Soil Gas Inv.	FB-090908		--	< .00273	< .00273	< .00202	< .00202	< .00198	NA	< .00132	< .00198	< .00339	< .00198	**0.051**	< .00128	NA	< .00492
		VMW-01 Initial Sample	Semi-Annual Soil Vapor Sampling at VMW-01	FB-01212008		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	0.005	< .0013	NA	< .0025
		VMW-01 Purge Test		FB-03172008		--	0.0077	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	0.0048	< .0013	NA	< .005
		VMW-01		FB-033108		--	0.0028	< .0028	< .0021	< .0021	< .002	NA	< .0013	< .002	< .0034	< .002	< .012	< .0013	NA	< .005
				FB-091008		--	< .00273	< .00273	< .00202	< .00202	< .00198	NA	< .00132	< .00198	< .00339	< .00198	< .00269	< .00128	NA	< .00492
				FB-03192009		--	< .00273	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	0.0052	< .00198	< .00269	< .00128	NA	0.032
				FB-091009		--	< .00273	< .00273	< .00202	< .00202	< .00198	< .177	< .00132	< .00198	< .00339	< .00198	< .00269	< .00128	NA	< .00492
				AA-03172010		--	0.01	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	< .00339	< .00198	0.025	< .00128	< 0.005 T4	0.071
				FB-09092010		--	0.017	< .0027	< .002	< .002	< .002	< .009	< .0013	< .002	< .0034	< .002	0.011	< .0013	NA	0.054
	Trip Blanks	Phase I Soil Gas Investigation	Trip Blanks	TB01-(0)-09192006		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	< .0025
				TB01-092006		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	0.006
				TB01-092106		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	< 0.002	0.0065
				TB01-(0.0)-092206		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	< 0.002	< .0025
				TB01-092506		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	< 0.002	< .0025
				TB02-092506		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	< 0.002	< .0025
				TB03-092506		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	< 0.002	0.013
		Phase II Soil Gas Investigation		TB01-(0)-12042007		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	< .005
				TB01-(0)-12102007		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	0.017	< .002	< .0028	< .0013	NA	0.042
		Phase III Soil Gas Inv		TB-090908		--	< .00273	< .00273	< .00202	< .00202	< .00198	NA	< .00132	< .00198	< .00339	< .00198	< .00269	< .00128	NA	< .00492
		VMW-01		TB-01212008		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	< .005
				TB-03172008		--	< .0028	< .0028	< .0021	< .0021	< .002	< .018	< .0013	< .002	< .0034	< .002	< .0028	< .0013	NA	0.008
				TB-033108		--	< .0028	< .0028	< .0021	< .0021	< .002	NA	< .0013	< .002	< .0034	< .002	0.0049	< .0013	NA	< .005
				TB-03192009		--	< .00273	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	0.0068	< .00198	< .00269	< .00128	NA	< .00492
				TB-091609		--	< .00273	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	< .00339	< .00198	< .00269	< .00128	NA	< .00492
				Trip Blank (03-17-2010)		--	< .00273	< .00273	< .00202	< .00202	< .00198	< .00901	< .00132	< .00198	< .00339	< .00198	0.002 J	< .00128	< 0.002	< .00492
				TB-09092010		--	< .0027	< .0027	< .002	< .002	< .002	< .009	< .0013	< .002	< .0034	< .002	< .0027	< .0013	NA	< .0049 U

Notes

All units are in mg/m^3 (milligrams per cubic meter)
bgs - below ground surface
TCA - Trichloroethane
DCA - Dichloroethane
DCE - Dichloroethene
PCE - Tetrachloroethene
TCE - Trichloroethene
IPA - Isopropyl Alcohol
NE - Not Established
SG - Soil Gas
NA - Not Analyzed
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
< - Constituent not detected at or above method reporting limit.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for Residential use Only.
D2 - Sample diluted

J - Poor field duplicate precision
T4 - Tentatively identified compound. Concentration is estimated and based on the closest internal standards.
FD - Field Duplicate
UJ - Result reported below the reporting limit, correlates to the E4 flag issued by laboratory
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test
UB - Compound considered non-detect at the listed value due to associated blank contamination.
E8 - Analyte reported to the method detection limit (MDL) per project specifications.
Target analyte was not detected in sample.
E4 - Concentration estimated. Analyte detected below laboratory minimum reporting level (MRL)
V2 - Indicates the second attempt for purge volume test event for the same borehole.
-- = Not Applicable
AA - Ambient Air
TB - Trip Blank
U - Analyte detected in ambient air sample or trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011 [February 2012 IRIS document for PCE]) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - Samples were reported as a whole for 1,2-Dichloroethylene (cis- and trans-1,2-DCE combined).
2 - Samples collected from the vapor monitoring wells have periodically been mislabeled at various times since they were installed. For the initial sampling for VMW-1 (January 2008), the samples were labeled as VW instead of VMW. Also, the depths for the screened interval have also been periodically mislabeled. The actual depths are as follows: VMW-01 (12.5', 40', 55', and 79.5' bgs), VMW-02 (10', 40', 55', and 79' bgs), VMW-03 (8', 35', 52', and 73' bgs), and VMW-04 (13', 50.5', and 75').
3 - Samples also used for the Soil Vapor Extraction Baseline Soil Vapor Sampling Event.
4 - Ambient Air sample can only be used to evaluate SG-54 through SG-56
5 - Ambient Air sample can only be used to evaluate SG-1 through SG-34
6 - Ambient Air sample can only be used to evaluate SG-57 through SG-60
7 - Ambient Air sample can only be used to evaluate SG-61 through SG-63
8 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table 3
Historical Groundwater Analytical Results
(Detected Motorola 52nd Street Superfund Site Constituents of Concern)
500 South 15th Street Facility, Phoenix, Arizona

Sample Information			Constituents of Concern (ug/L)								
Location ID	Sample ID	Sample Date	1,1-DCA	1,1-DCE	1,2-DCE	1,4-Dioxane	1,1,1-TCA	1,1,2-TCA	cis-1,2-DCE	PCE	TCE
MW-1	MW01-01141992	1/14/1992	0.3	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.5
MW-1	MW01-04301992	4/30/1992	< 0.2 U	2.1	< 0.2 U	NA	0.5	< 0.2 U	NA	0.4	2.8
MW-1	MW01-07201992	7/20/1992	< 0.2 U	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	2.2
MW-1	MW01-10271992	10/27/1992	< 0.2 U	0.6	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	2.1
MW-1	MW01-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-2	MW02-01141992	1/14/1992	< 0.2 U	0.3	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	0.2	2.1
MW-2	MW02-04301992	4/30/1992	0.3	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	0.2	0.7
MW-2	MW02-07201992	7/20/1992	< 0.2 U	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.8
MW-2	MW02-10271992	10/27/1992	< 0.2 U	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	2.1
MW-2	MW02-12011994	12/1/1994	< 0.2 U	< 0.2 U	NA	NA	< 1 U	< 0.2 U	< 0.2 U	< 0.5 U	< 0.2 U
MW-2	MW02-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-2	MW03-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-2	AA-MW-2	9/9/2002	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-3	MW03-01141992	1/14/1992	1.1	0.4	0.4	NA	< 0.2 U	< 0.2 U	NA	0.5	1.8
MW-3	MW03-04301992	4/30/1992	1.1	1	0.3	NA	< 0.2 U	< 0.2 U	NA	0.5	2.4
MW-3	MW03-07201992	7/20/1992	1.2	0.6	0.4	NA	< 0.2 U	< 0.2 U	NA	0.4	1.4
MW-3	MW03-10271992	10/27/1992	0.7	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	0.2	0.8
MW-3	MW03-12011994	12/1/1994	< 0.2 U	< 0.2 U	NA	NA	< 1 U	< 0.2 U	< 0.2 U	< 0.5 U	< 0.2 U
MW-3	MW3-092905	9/29/2005	< 1 U	< 1 U	NA	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-3	MW0303282006	3/28/2006	< 0.5 U	< 0.5 U	NA	< 1 U	< 0.5 U	< 0.5 U	< 0.5 U	< 0.5 U	< 0.5 U
MW-3	DUP03292007	3/29/2007	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-3	MW303292007	3/29/2007	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-4	MW04-01141992	1/14/1992	4.5	3.3	2.6	NA	2	< 0.2 U	NA	0.6	**23**
MW-4	MW04-04301992	4/30/1992	5.2	3.6	3.6	NA	1.8	< 0.2 U	NA	0.6	**27**
MW-4	MW07-04301992	4/30/1992	5.6	3.8	3.9	NA	2	< 0.2 U	NA	0.7	**30**
MW-4	MW04-07201992	7/20/1992	12	6.3	8.8	NA	< 0.2 U	< 0.2 U	NA	0.9	**59**
MW-4	MW07-07201992	7/20/1992	11	5.4	7.8	NA	3.8	0.3	NA	0.7	**52**
MW-4	MW04-10271992	10/27/1992	6.9	3.3	5.2	NA	2.4	< 0.2 U	NA	0.8	**40.8**
MW-4	MW07-10271992	10/27/1992	7.1	3.9	5.2	NA	2.6	< 0.2 U	NA	0.7	**40.3**
MW-4	MW04-12011994	12/1/1994	< 0.2 U	0.2	NA	NA	< 1 U	< 0.2 U	0.2	< 0.5 U	**12**
MW-4	MW04-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	**14**
MW-4	MW07-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-4	MW4-092905	9/29/2005	< 1 U	< 1 U	NA	NA	< 1 U	< 1 U	< 1 U	< 1 U	**22**
MW-4	FD0103282006	3/28/2006	0.68	< 0.5 U	NA	2.8	< 0.5 U	< 0.5 U	0.73	< 0.5 U	**17**
MW-4	MW0403282006	3/28/2006	0.69	< 0.5 U	NA	2.5	< 0.5 U	< 0.5 U	0.79	< 0.5 U	**17**
MW-4	MW403292007	3/29/2007	< 1 U	< 1 U	NA	2.5	< 1 U	< 1 U	< 1 U	< 1 U	**13**
MW-4	MW403282008	3/28/2008	< 1	< 1	NA	4.4	< 1	< 1	< 1	< 1	**17**
MW-4	MW4-09162008	9/16/2008	<1	<1	NA	2.4	<1	<1	<1	<1	**9.1**
MW-4	MW4-03182009	3/18/2009	<1	<1	NA	<1	<1	<1	<1	<1	4.4
MW-4	DUP-03182009	3/18/2009	<1	<1	NA	<1	<1	<1	<1	<1	4.4
MW-4	MW4-090909	9/9/2009	<1	<1	NA	<1	<1	<1	<1	<1	4.8
MW-4	MW4-03162010	3/16/2010	<1	<1	NA	NA	<1	<1	<1	<1	**6.9**
MW-4	MW4-04152010	4/15/2010	<1	<1	NA	<1	<1	<1	<1	<1	**5.1**
MW-4	MW4-09082010	9/8/2010	<1	<1	NA	<1	<1	<1	<1	<1	3.8
MW-4	DUP-09082010	9/8/2010	<1	<1	NA	<1	<1	<1	<1	<1	3.6
MW-4	MW4-03172011	3/17/2011	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	2.4
MW-4	DUP-03172011	3/17/2011	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	2.4
MW-5	MW05-01141992	1/14/1992	< 0.2 U	0.8	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	1.6
MW-5	MW05-04301992	4/30/1992	< 0.2 U	0.5	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	0.2	0.4
MW-5	MW05-07201992	7/20/1992	< 0.2 U	0.4	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.6
MW-5	MW05-10271992	10/27/1992	< 0.2 U	0.2	0.2	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.7
MW-5	MW05-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-5	AA-MW-5	9/9/2002	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-6	MW06-01141992	1/14/1992	< 0.2 U	0.4	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.4
MW-6	MW06-04301992	4/30/1992	< 0.2 U	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U
MW-6	MW06-07201992	7/20/1992	0.3	< 0.2 U	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	2.2
MW-6	MW06-10271992	10/27/1992	< 0.2 U	0.5	< 0.2 U	NA	< 0.2 U	< 0.2 U	NA	< 0.2 U	0.5
MW-6	MW06-09071999	9/7/1999	< 5 U	< 5 U	< 5 U	NA	< 5 U	< 5 U	< 5 U	< 5 U	< 5 U
MW-7	DUP-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-7	MW7-100-012208	1/22/2008	< 1 U	< 1 U	NA	< 1.1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-7	MW7-106-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-7	MW7-92-012208	1/22/2008	< 1 U	< 1 U	NA	1.3	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-7	DUP-03282008	3/28/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-7	MW7-03282008	3/28/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-7	DUP-09162008	9/16/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-7	MW7-09162008	9/16/2008	< 1	< 1	NA	1	< 1	< 1	< 1	< 1	< 1
MW-7	MW7-03182009	3/18/2009	<1	<1	NA	1.2	<1	<1	<1	<1	**5.4**
MW-7	MW7-090909	9/9/2009	<1	<1	NA	1.4	<1	<1	<1	<1	**5.5**
MW-7	DUP-090909	9/9/2009	<1	<1	NA	1.3	<1	<1	<1	<1	4.6
MW-7	MW7-03162010	3/16/2010	<1	<1	NA	NA	<1	<1	<1	<1	4.5
MW-7	DUP-03162010	3/16/2010	<1	<1	NA	NA	<1	<1	<1	<1	4.1
MW-7	MW7-04152010	4/15/2010	<1	<1	NA	3.4	<1	<1	<1	<1	**9.6**
MW-7	DUP-04152010	4/15/2010	<1	<1	NA	3.2	<1	<1	<1	<1	**10**
MW-7	MW7-09082010	9/8/2010	<1	<1	NA	1.1	<1	<1	<1	<1	**5.7**
MW-7	MW7-03172011	3/17/2011	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	3.2
MW-8	MW8-106-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-8	MW8-92-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-8	MW8-99-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-8	MW8-03282008	3/28/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-8	MW8-09162008	9/16/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-8	MW8-03182009	3/18/2009	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-8	MW8-090909	9/9/2009	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-8	MW8-03162010	3/16/2010	<1	<1	NA	NA	<1	<1	<1	<1	<1
MW-8	MW8-04152010	4/15/2010	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-8	MW8-09082010	9/8/2010	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-8	MW8-03172011	3/17/2011	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
MW-9	MW9-100-012208	1/22/2008	< 1 U	< 1 U	NA	< 1.1 U	< 1 U	< 1 U	< 1 U	< 1 UJ	< 1 U
MW-9	MW9-107-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
MW-9	MW9-92-012208	1/22/2008	< 1 U	< 1 U	NA	< 1 U	< 1 U	< 1 U	< 1 U	< 1 UJ	< 1 U
MW-9	MW9-03282008	3/28/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-9	MW9-09162008	9/16/2008	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1
MW-9	MW9-03182009	3/18/2009	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-9	MW9-090909	9/9/2009	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-9	MW9-03162010	3/16/2010	<1	<1	NA	NA	<1	<1	<1	<1	<1
MW-9	MW9-04152010	4/15/2010	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-9	MW9-09082010	9/8/2010	<1	<1	NA	<1	<1	<1	<1	<1	<1
MW-9	MW9-03172011	3/17/2011	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
USEPA MCL/ADEQ AWQS			NE	7	NE	NE	200	5	70	5	5

NOTES:

ug/l	micrograms per liter	<	Less than
1,1-DCA	1,1-Dichloroethane	U	Not detected at or above method report limit
1,1-DCE	1,1-Dichloroethene	NA	Not analyzed - 1,2-DCE is now differentiated by its isomers cis-1,2-DCE and trans-1,2-Dichloroethene (trans 1,2-DCE)
1,2-DCE	1,2-Dichloroethene (Total)	**Bold**	Concentration exceeds the USEPA MCL/ADEQ AWQS
1,1,1-TCA	1,1,1-Trichloroethane	Grey shading indicates current sampling event	
1,1,2-TCA	1,1,2-Trichloroethane	NE	Not established
cis-1,2-DCE	cis-1,2-Dichloroethene	USEPA MCL/ADEQ AWQS	USEPA Maximum Contaminat Level (MCL)/ Arizona Department of Environmental Quality (ADEQ) Arizona Water Quality Standards
PCE	Tetrachloroethene		
TCE	Trichloroethene		

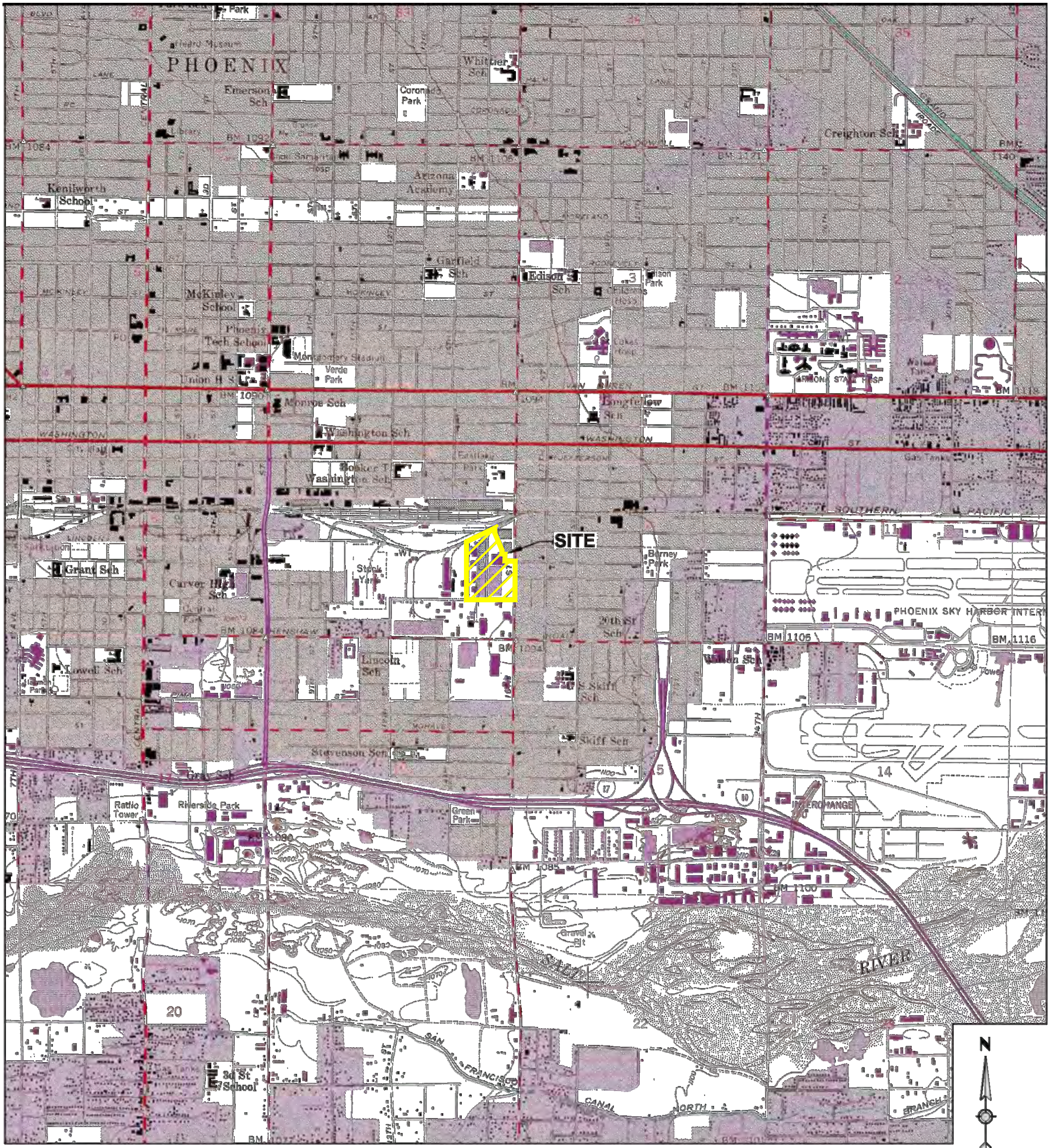
Table 4 Groundwater Inflows and Outflows Calibration Results
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Flood Season, Represented September 1993, model stress period 65				
	CPM Inflow	**Facility Model Inflow**	**CPM Outflow**	**Facility Model Outflow**
	cfs	cfs	cfs	cfs
Storage	0	0	65.1	65.9
Recharge	3.8	3.7	0	0
River	151.0	153.6	0	0
Well	0	0	79.7	79.8
Non-flood Season, Represented by December 1998, model stress period 81				
	CPM Inflow	**Facility Model Inflow**	**CPM Outflow**	**Facility Model Outflow**
	cfs	cfs	cfs	cfs
Storage	9.4	9.1	30.7	32.7
Recharge	2.5	2.7	0	0
River	15.4	15.2	0	0
Well	0	0	18.2	17.6

CPM = Central Phoenix Plume Model
cfs = cubic feet per second

Table 5 Summary of Solute Transport Scenarios and Their Associated Key Parameters
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

		Dual Domain Parameters		Dispersivity			Biodegradation	Foc
		Mobile Porosity	Immobile Porosity	Longitudinal (ft)	Transverse (ft)	Vertical (ft)	Half Life in days	Unitless
Base Case	Scenario 1a	0.2	0.17	80	8	0.8	4,950	0.002
	Scenario 1b	0.2	0.08	80	8	0.8	4,950	0.002
	Scenario 1c	0.2	0.17	80	8	0.8	No Biodegradation	0.002
	Scenario 1d	0.2	0.17	80	8	0.8	4,950	0.001
More Conservative Case	Scenario 2	0.2	0.08	None			No Biodegradation	No sorption/desorption
Less Conservative Case	Scenario 3	0.25	0.25	80	8	0.8	277	0.002



SOURCE: USGS
PHOENIX, AZ
QUADRANGLE

NOT TO SCALE

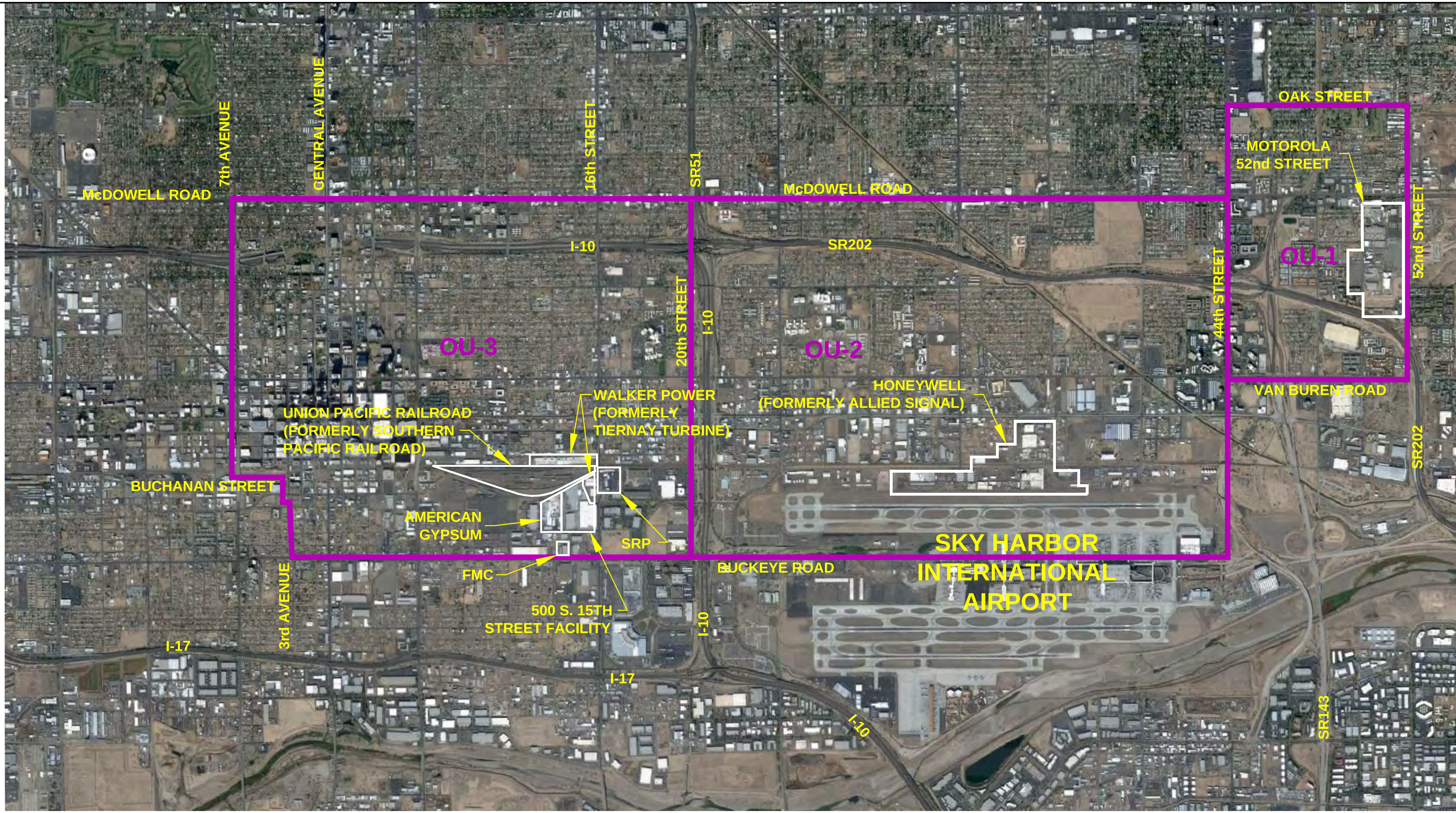
ARCADIS
410 N. 44th Street Suite 1000
Phoenix, AZ 85008-6503
Tel: 602.438.0883
Fax: 602.438.0102
www.arcadis-us.com

Groundwater Flow and Solute Transport Modeling Report

VICINITY MAP

500 South 15th Street Facility
Phoenix, Arizona

FIGURE 1



EXPLANATION

OU-3 MOTOROLA OPERABLE UNIT (OU) STUDY AREA

OU BOUNDARIES

NOTE: ADAPTED FROM SHAW ENVIRONMENTAL, 2004

0 .25 .5

SCALE IN MILES

Date\Time : Wed, 23 Jan 2013 – 4:49pm
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MOTOROLA 52ND STREET SUPERFUND SITE
OPERABLE UNITS
500 South 15th Street Facility
Phoenix, Arizona

FIGURE
2

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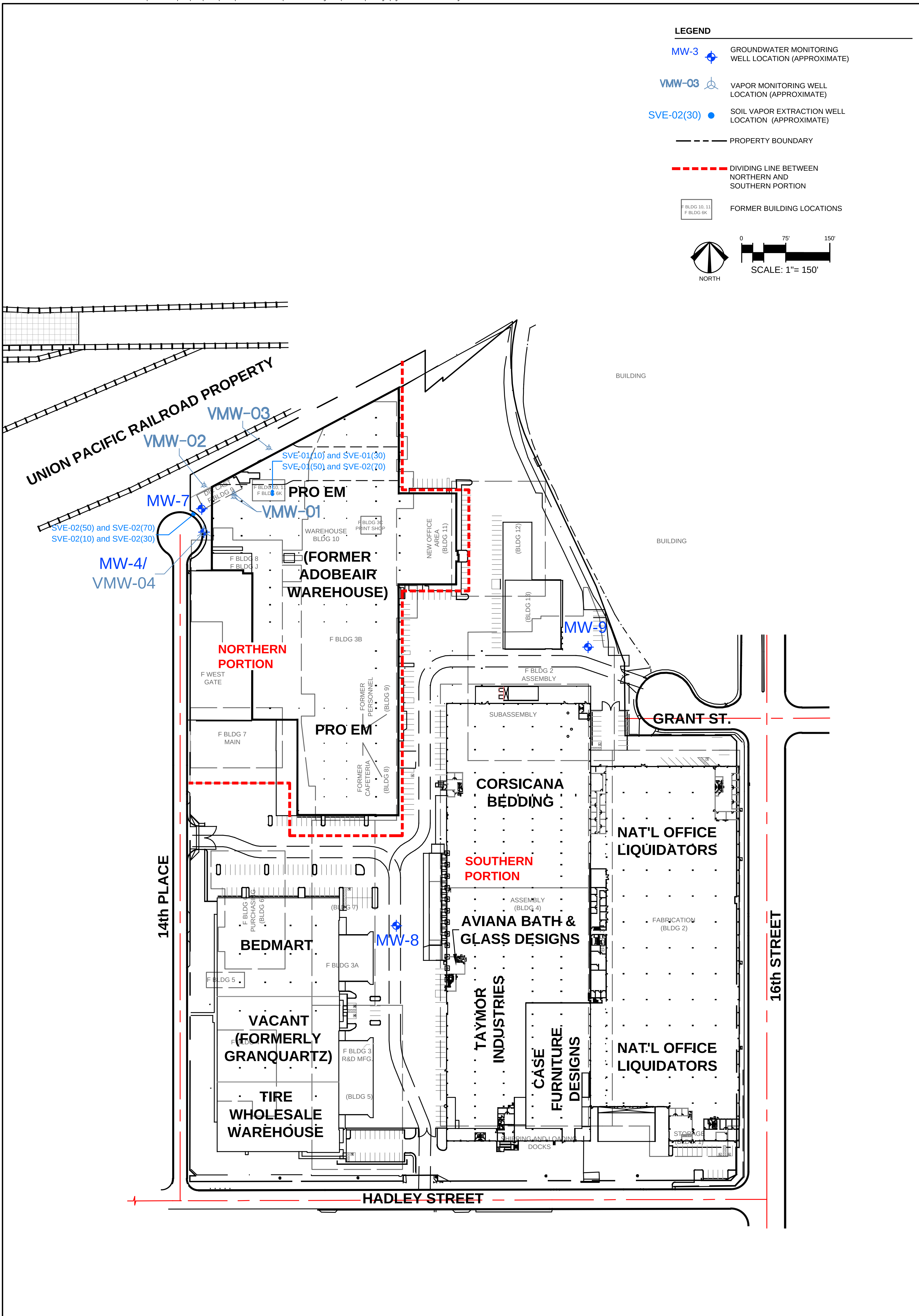

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HISTORIC BUILDING LAYOUT AND CURRENT SITE PLAN

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FIGURE

3

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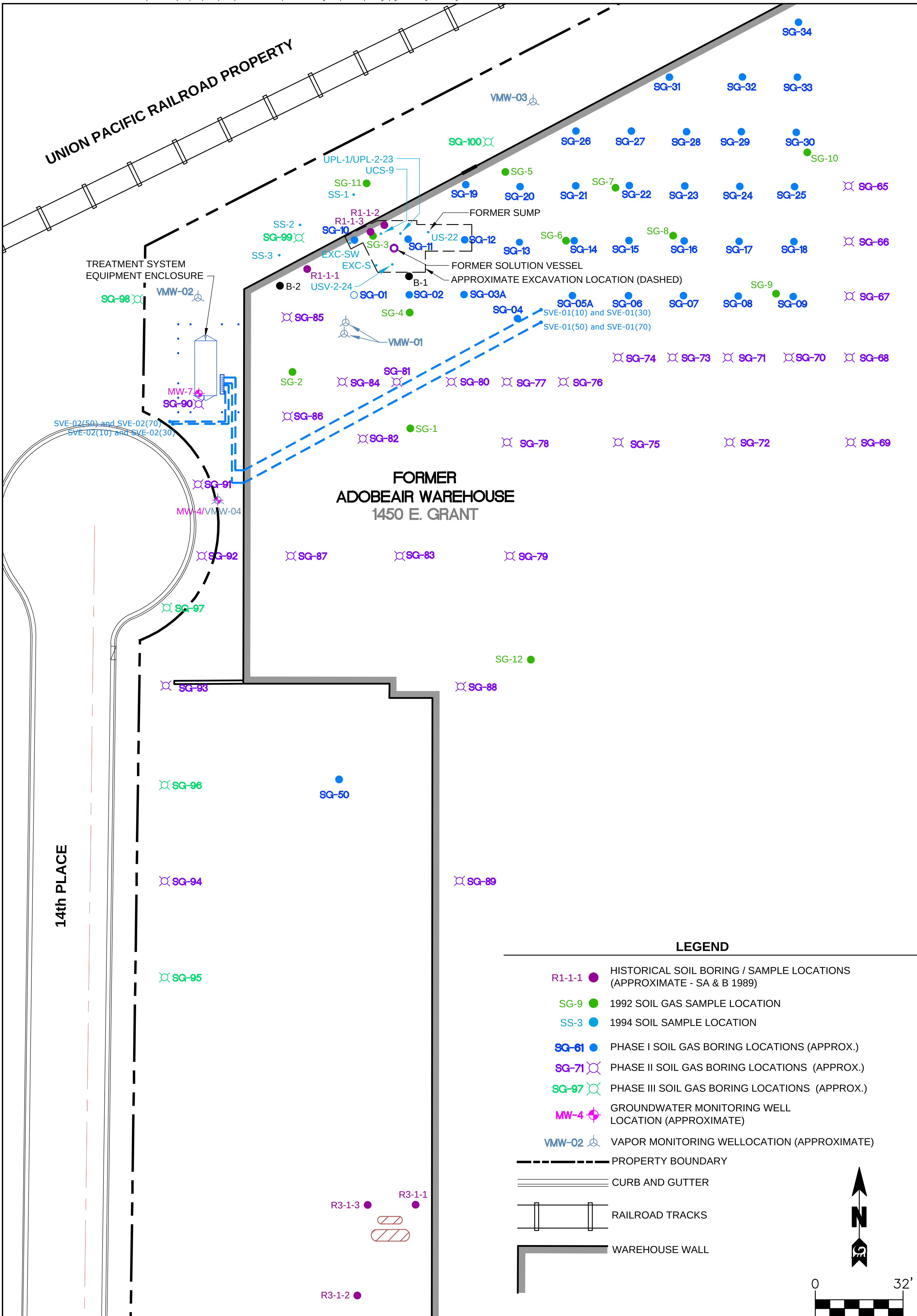

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SAMPLE LOCATIONS IN AND AROUND FORMER ADOBEAIR WAREHOUSE

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FIGURE

4

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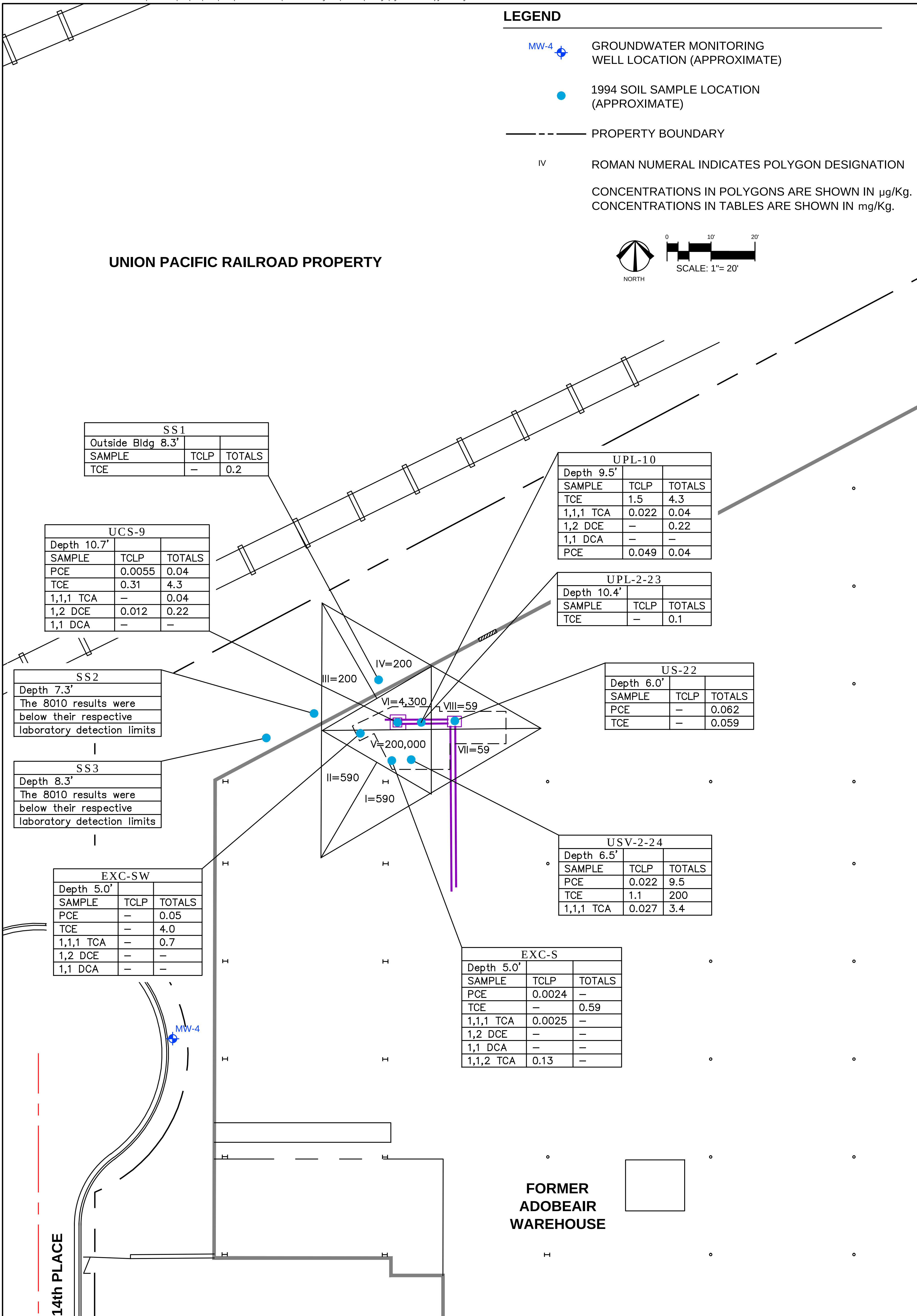

SS1

Outside Bldg 8.3'		
SAMPLE	TCLP	TOTALS
TCE	–	0.2

UCS-9

Depth 10.7'		
SAMPLE	TCLP	TOTALS
PCE	0.0055	0.04
TCE	0.31	4.3
1,1,1 TCA	–	0.04
1,2 DCE	0.012	0.22
1,1 DCA	–	–

SS2

Depth 7.3'
The 8010 results were below their respective laboratory detection limits

SS3

Depth 8.3'
The 8010 results were below their respective laboratory detection limits

EXC-SW

Depth 5.0'		
SAMPLE	TCLP	TOTALS
PCE	–	0.05
TCE	–	4.0
1,1,1 TCA	–	0.7
1,2 DCE	–	–
1,1 DCA	–	–

UPL-10

Depth 9.5'		
SAMPLE	TCLP	TOTALS
TCE	1.5	4.3
1,1,1 TCA	0.022	0.04
1,2 DCE	–	0.22
1,1 DCA	–	–
PCE	0.049	0.04

UPL-2-23

Depth 10.4'		
SAMPLE	TCLP	TOTALS
TCE	–	0.1

US-22

Depth 6.0'		
SAMPLE	TCLP	TOTALS
PCE	–	0.062
TCE	–	0.059

USV-2-24

Depth 6.5'		
SAMPLE	TCLP	TOTALS
PCE	0.022	9.5
TCE	1.1	200
1,1,1 TCA	0.027	3.4

EXC-S

Depth 5.0'		
SAMPLE	TCLP	TOTALS
PCE	0.0024	–
TCE	–	0.59
1,1,1 TCA	0.0025	–
1,2 DCE	–	–
1,1 DCA	–	–
1,1,2 TCA	0.13	–

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LOCATION OF VLEACH POLYGONS

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FIGURE 5

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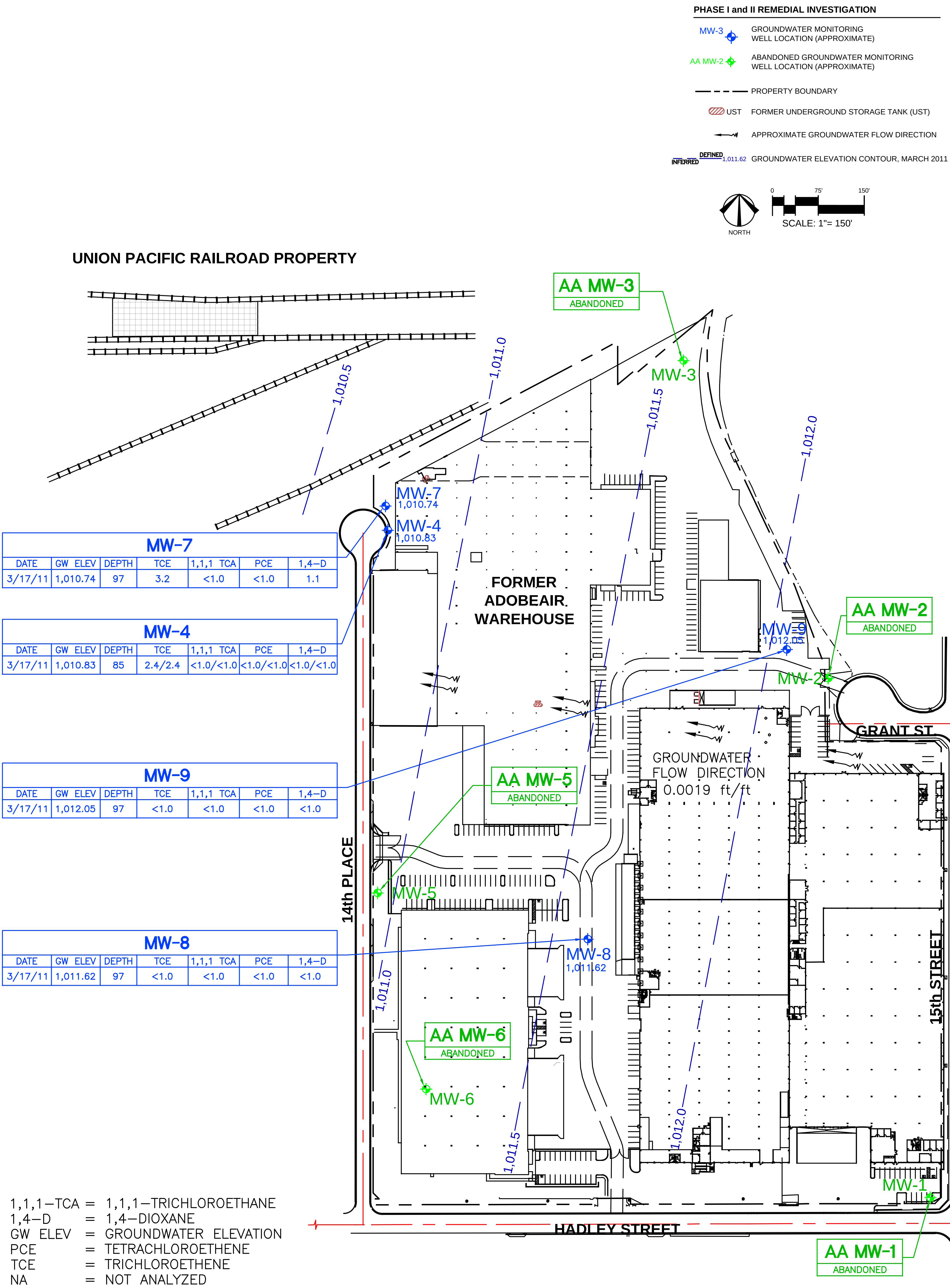

MW-7						
DATE	GW ELEV	DEPTH	TCE	1,1,1 TCA	PCE	1,4–D
3/17/11	1,010.74	97	3.2	<1.0	<1.0	1.1

MW-4						
DATE	GW ELEV	DEPTH	TCE	1,1,1 TCA	PCE	1,4–D
3/17/11	1,010.83	85	2.4/2.4	<1.0/<1.0	<1.0/<1.0	<1.0/<1.0

MW-9						
DATE	GW ELEV	DEPTH	TCE	1,1,1 TCA	PCE	1,4–D
3/17/11	1,012.05	97	<1.0	<1.0	<1.0	<1.0

MW-8						
DATE	GW ELEV	DEPTH	TCE	1,1,1 TCA	PCE	1,4–D
3/17/11	1,011.62	97	<1.0	<1.0	<1.0	<1.0

1,1,1–TCA = 1,1,1–TRICHLOROETHANE
1,4–D = 1,4–DIOXANE
GW ELEV = GROUNDWATER ELEVATION
PCE = TETRACHLOROETHENE
TCE = TRICHLOROETHENE
NA = NOT ANALYZED

NOTES:
1. CONSTITUENT CONCENTRATIONS IN GROUNDWATER ARE SHOWN IN MICROGRAMS PER LITER (μg/L).
2. GROUNDWATER ELEVATION IS IN FEET ABOVE MEAN SEA LEVEL.
3. DEPTH IS FEET BELOW MEASURING POINT WHERE SAMPLE IS COLLECTED.

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MARCH 2011 GROUNDWATER MONITORING AND SAMPLING DATA

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
6

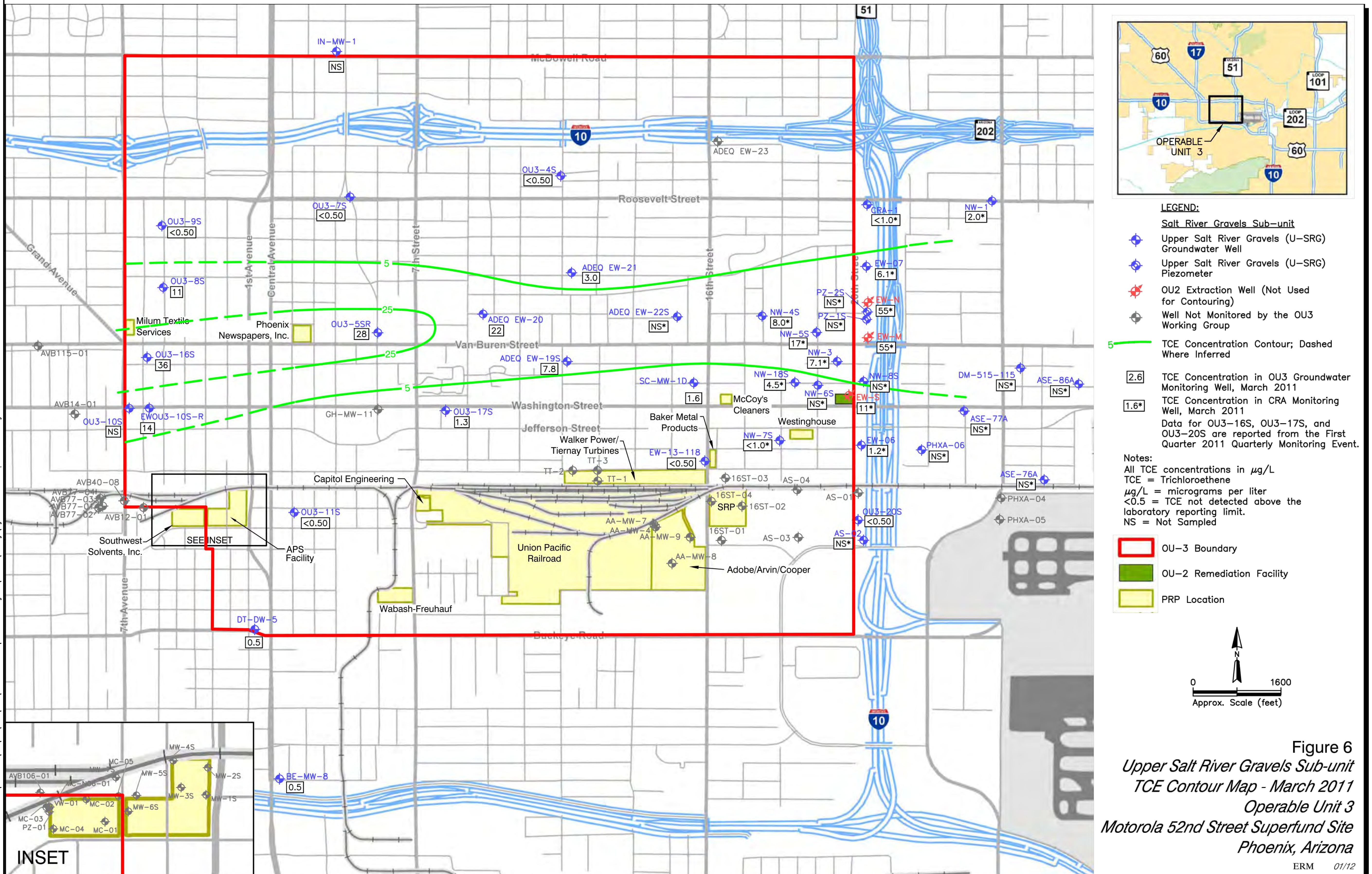

FIGURE 7 ADAPTED FROM ENVIRONMENTAL RESOURCES MANAGEMENT

TCE CONTOUR MAP UPPER SALT RIVER GRAVELS FOR MARCH 2011

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FIGURE 7

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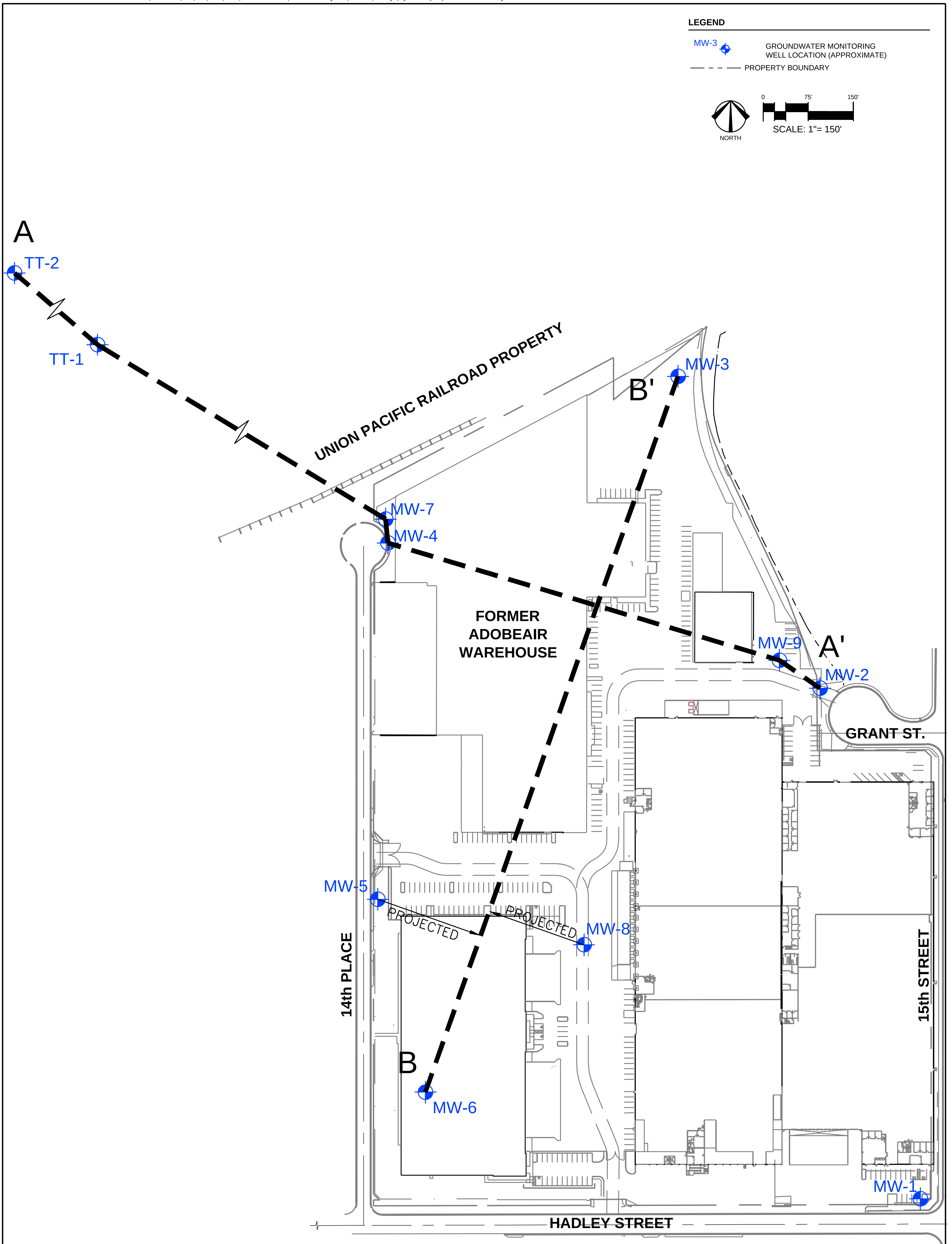

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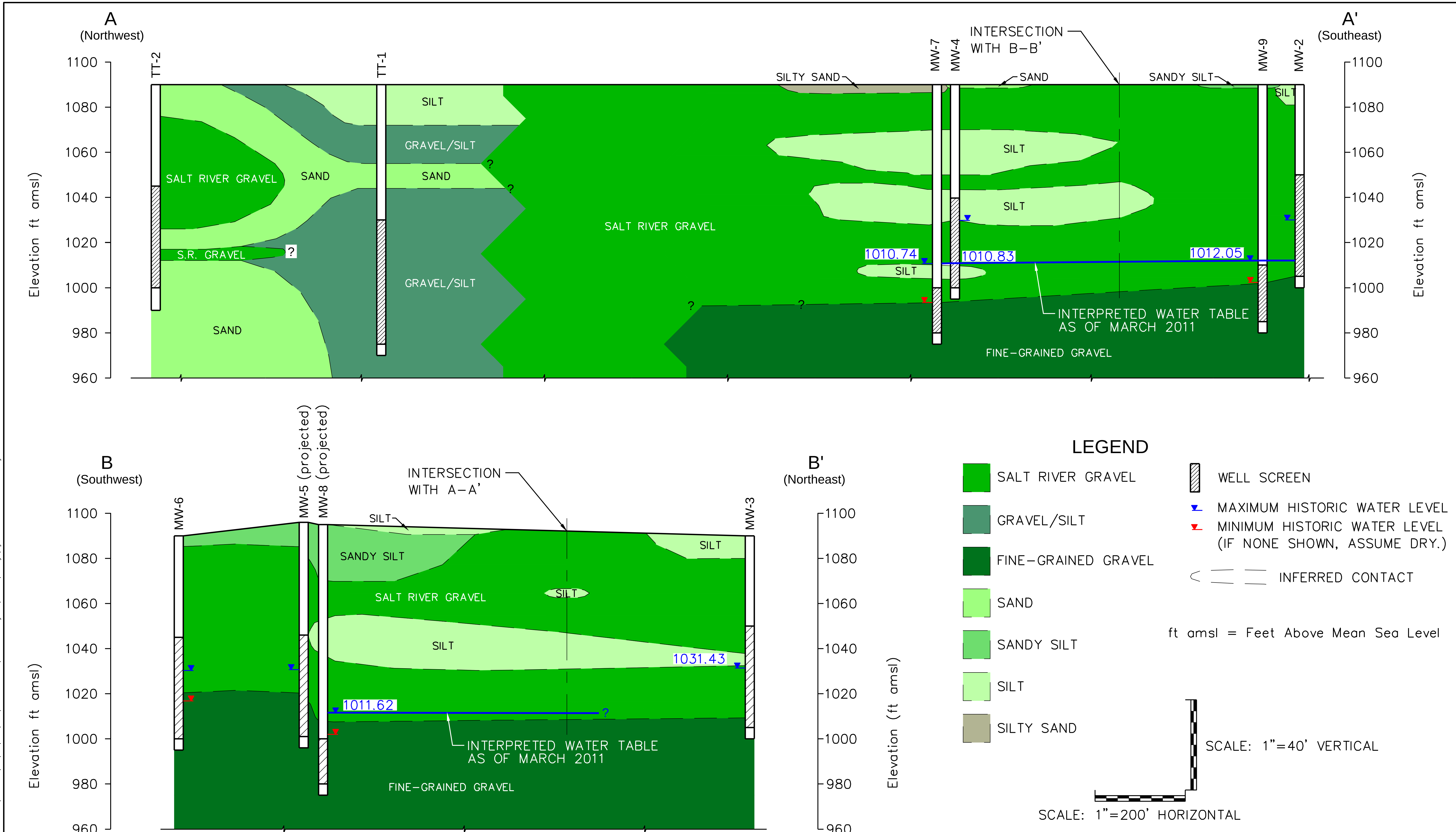
FACILITY LAYOUT AND CROSS-SECTION LOCATIONS

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
8



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CROSS-SECTIONS A-A' and B-B'

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Phoenix, Arizona

FIGURE
9

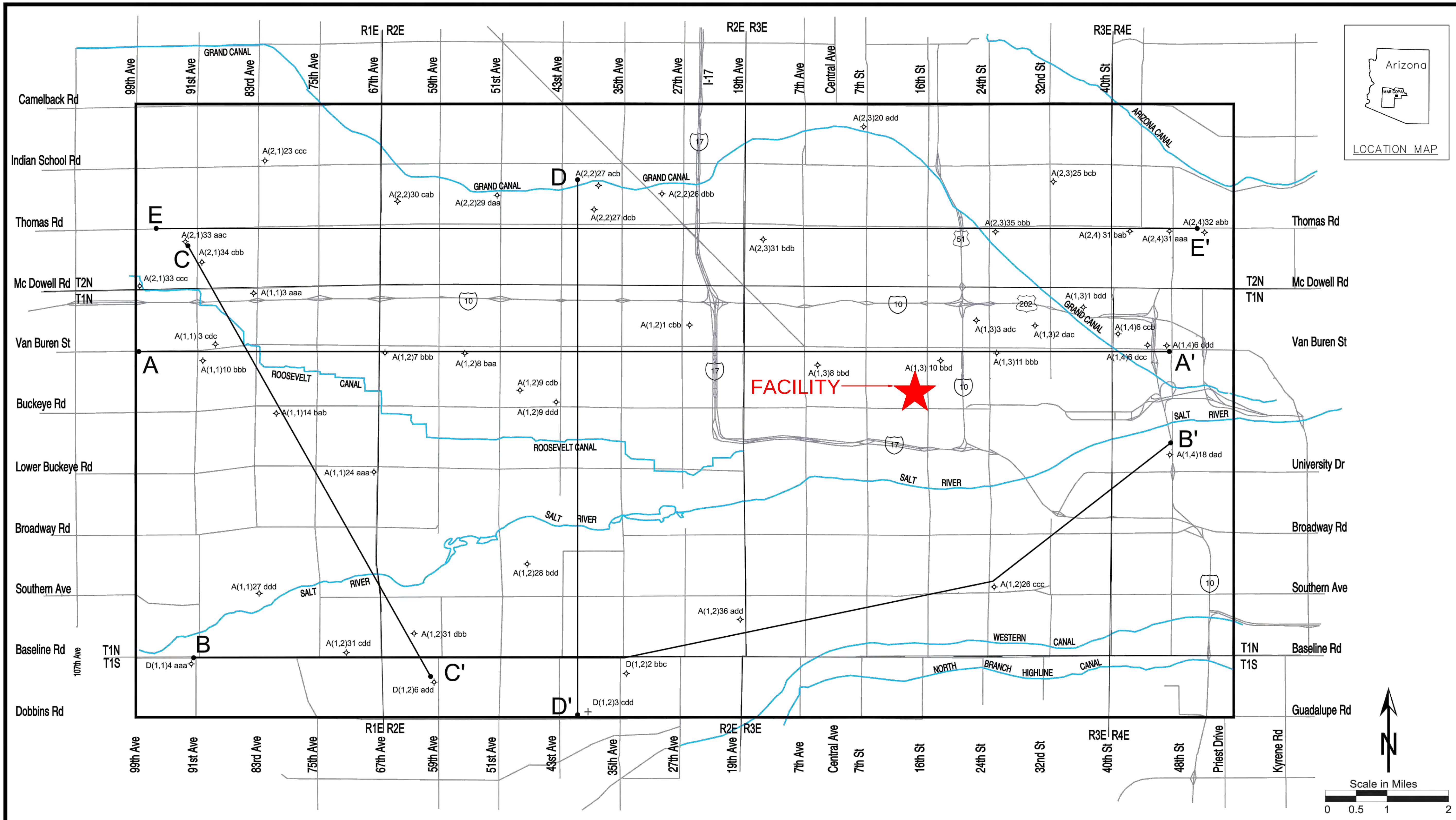

FIGURE 10

CPM MODEL DOMAIN SHOWING GEOLOGIC CROSS-SECTION LOCATIONS

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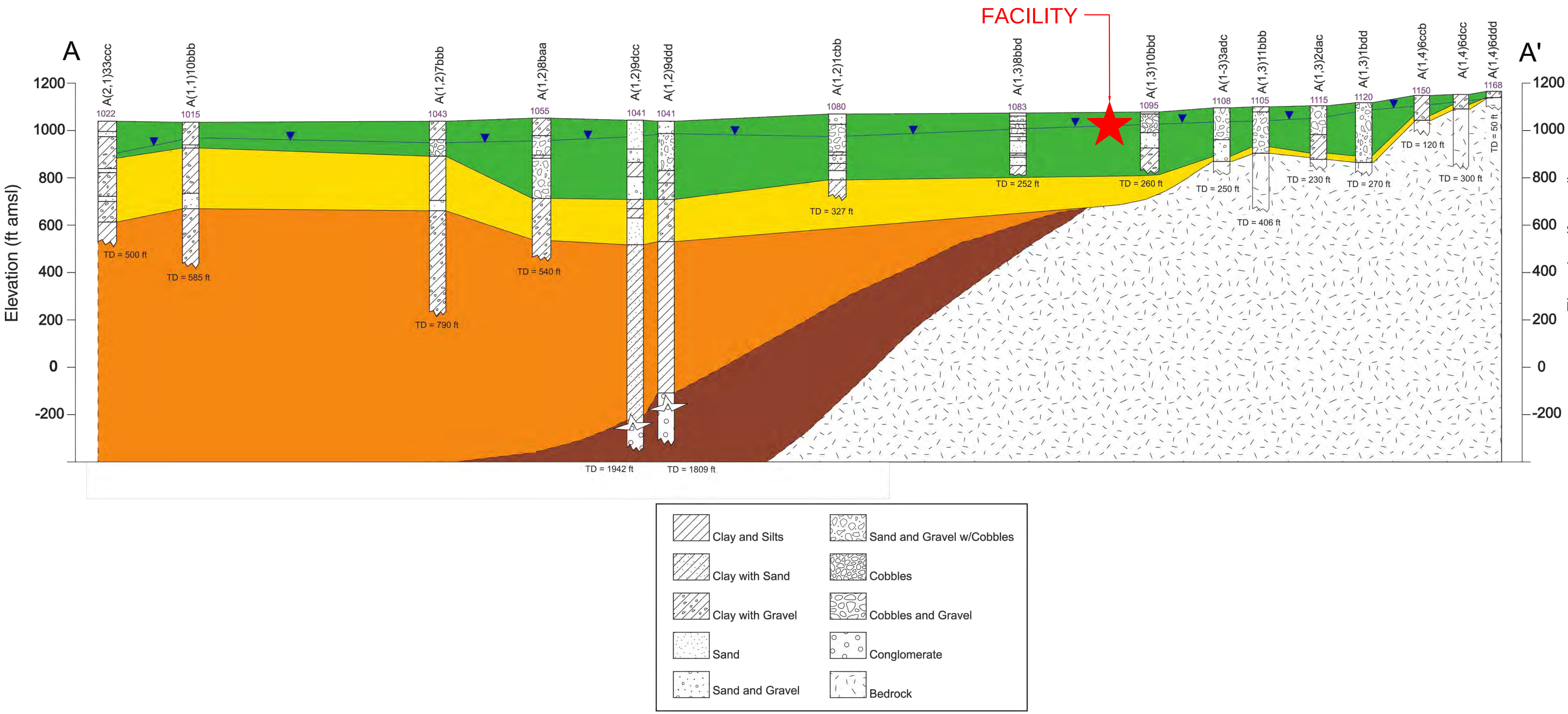
Adapted from WESTON, 2000



Water Table Based on 1991 Water Level Map (see fig. 12)

UAU1

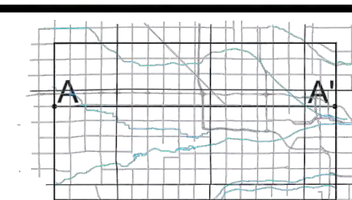
UAU2

MAU (undivided)

LAU

1056 Borehole Surface Elevation (ft. amsl)

Approximate Horizontal Scale
1 in = 1.25 mi



Locator Map

Adapted from WESTON, 2000

FIGURE 11

CPM MODEL EAST-WEST CROSS-SECTION A-A'

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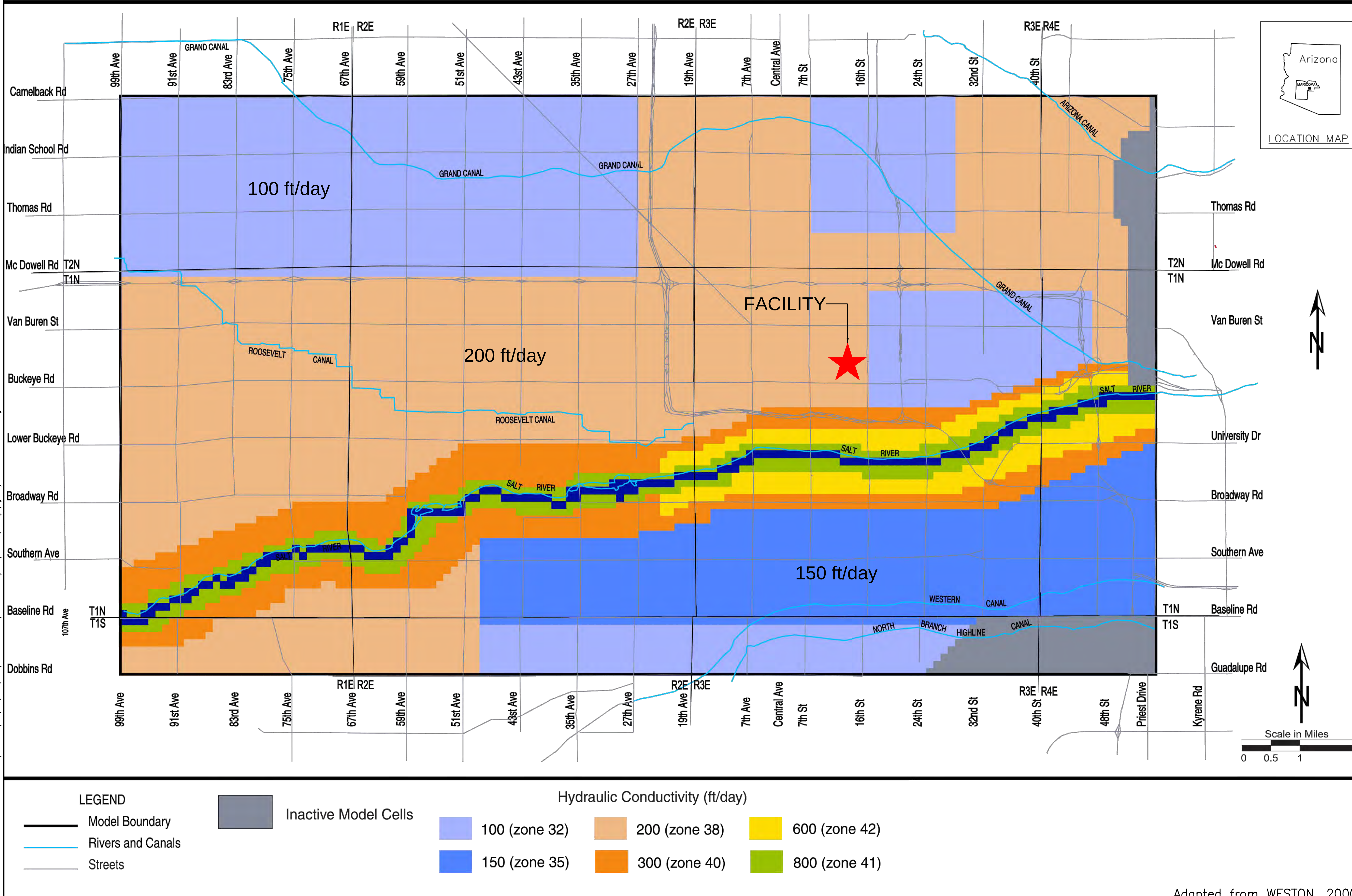

Adapted from WESTON, 2000

FIGURE 12

CPM MODEL HYDRAULIC CONDUCTIVITY IN THE UPPER PORTION OF THE UPPER ALLUVIAL UNIT

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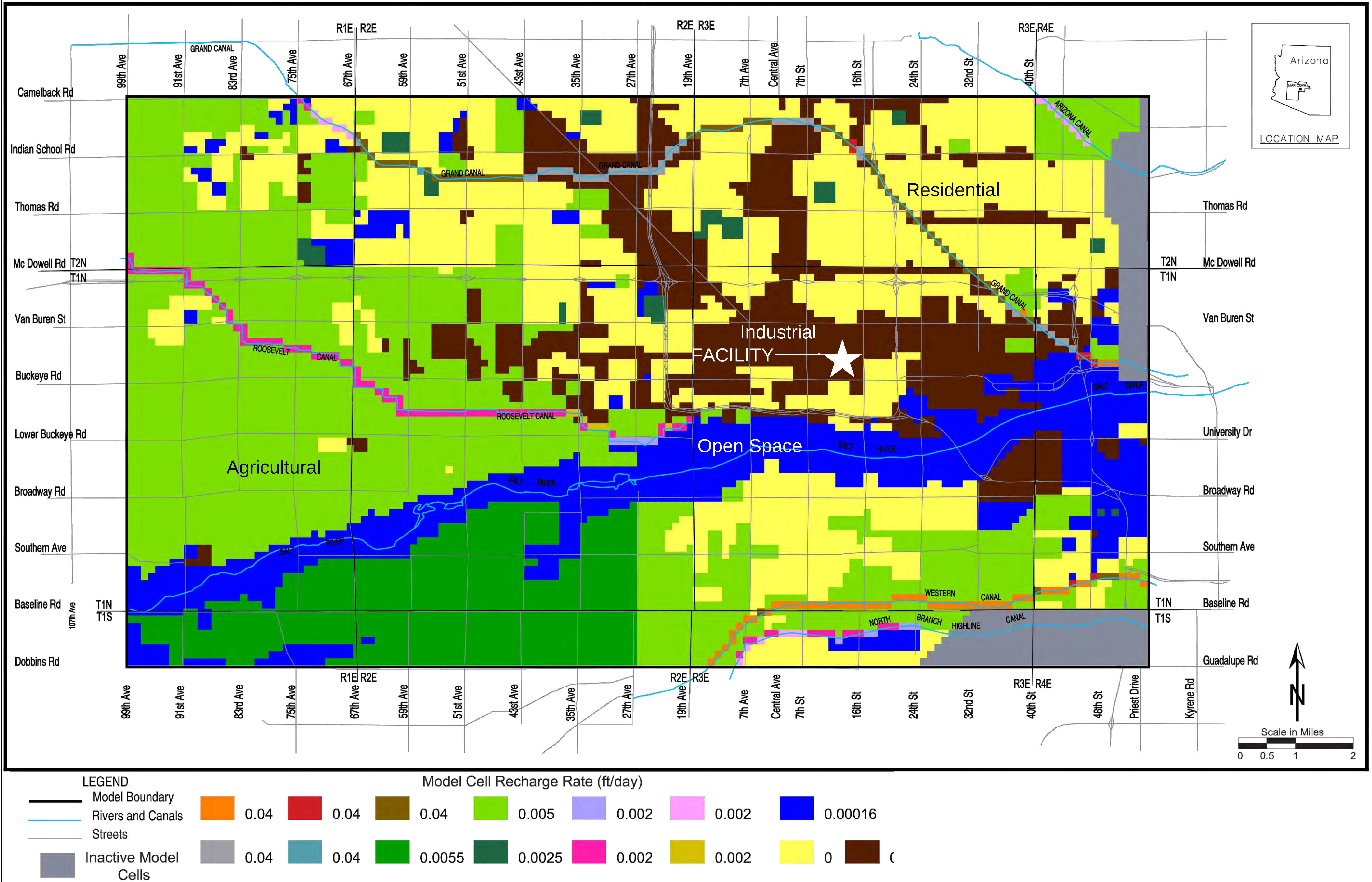

Adapted from WESTON, 2000

FIGURE 13

CPM MODEL RECHARGE RATES

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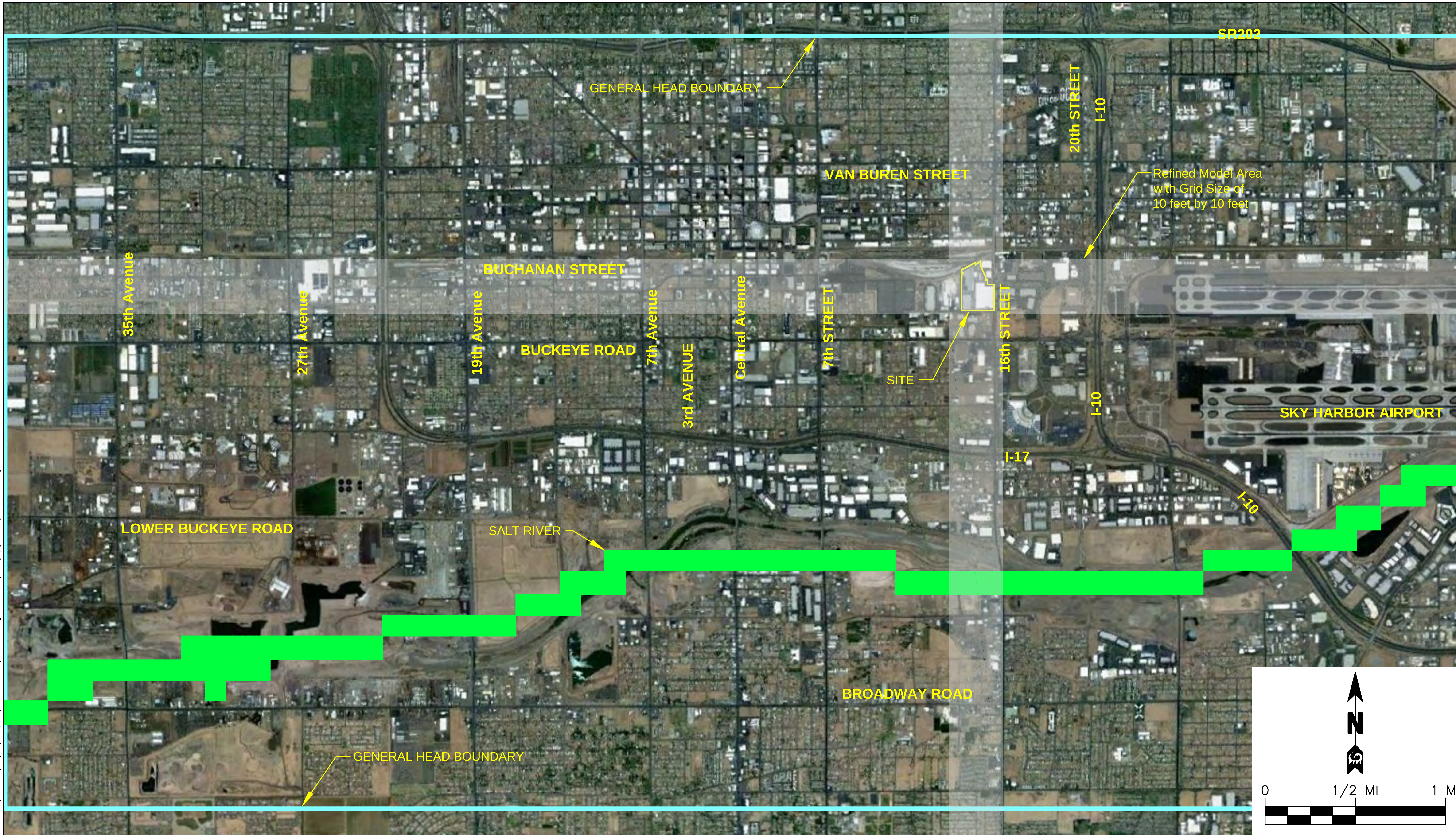

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FACILITY MODEL EXTENT AND BOUNDARY CONDITIONS

500 South 15th Street Facility
Phoenix, Arizona

FIGURE **14**

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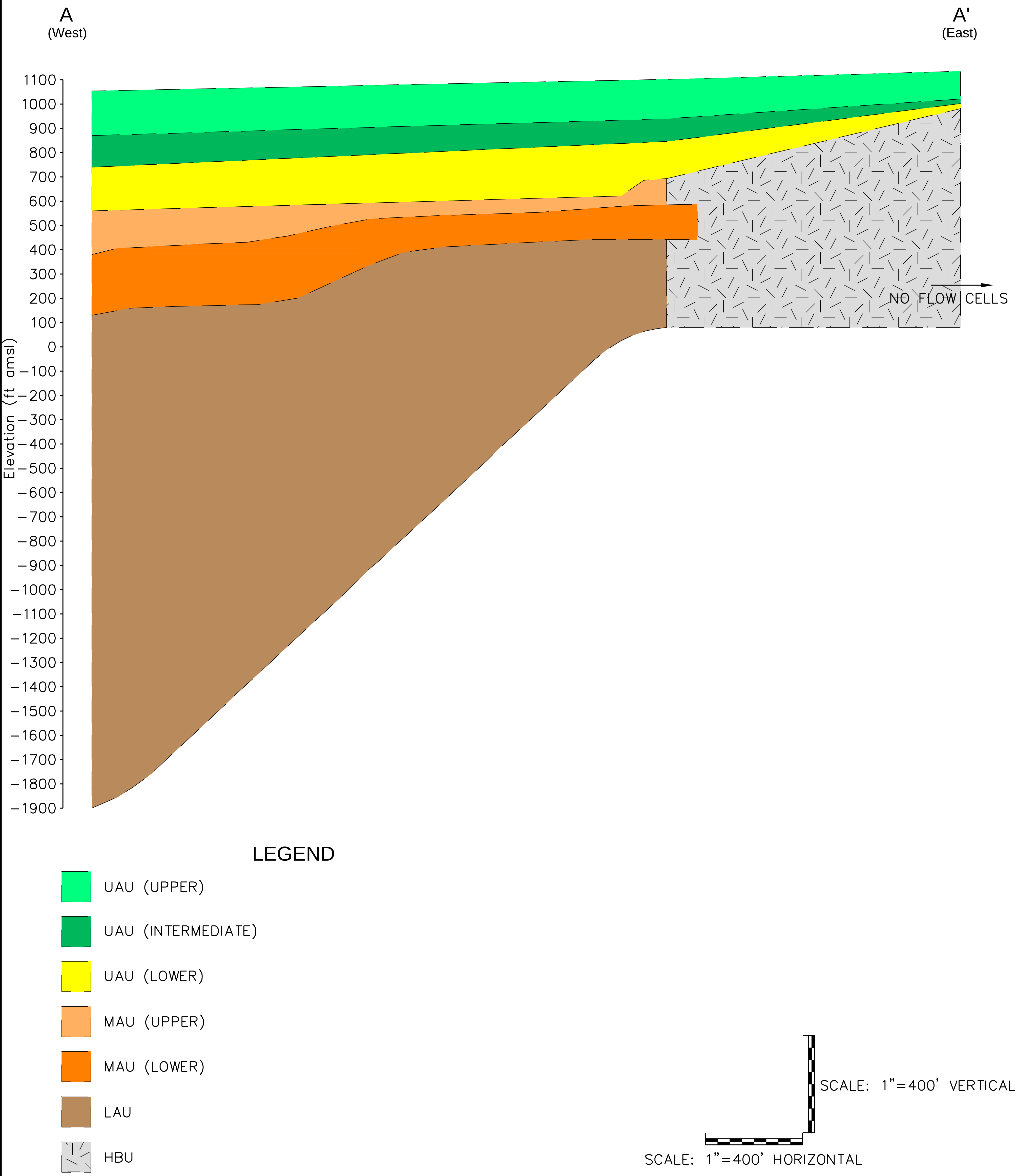

UAU: UPPER ALLUVIAL UNIT
MAU: MIDDLE ALLUVIAL UNIT
LAU: LOWER ALLUVIAL UNIT
HBU: HYDROLOGIC BEDROCK UNIT

ft amsl = Feet Above Mean Sea Level

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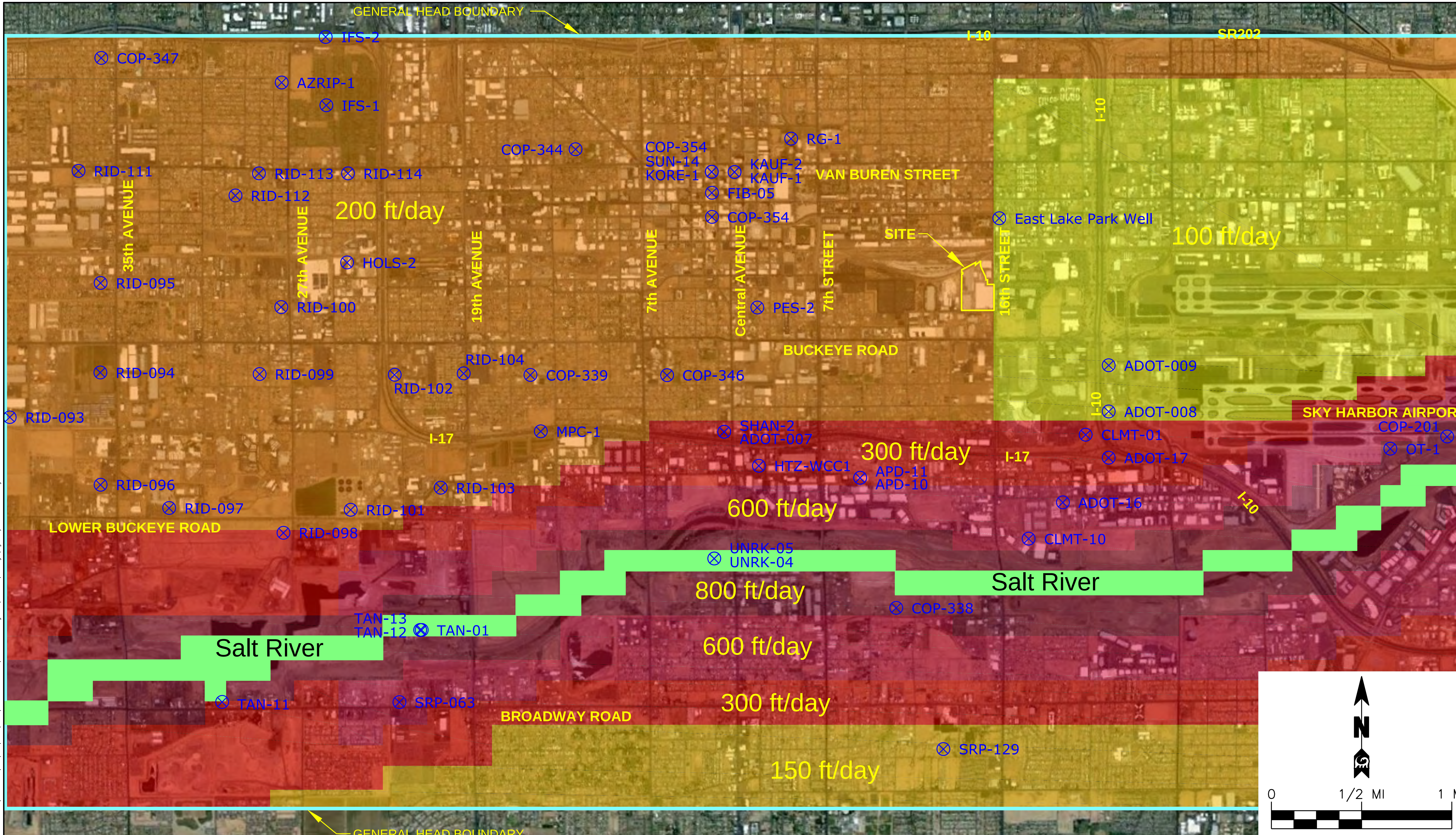
MODEL LAYERS AND THEIR ASSOCIATED HYDROSTRATIGRAPHIC UNITS
500 South 15th Street Facility
Phoenix, Arizona

FIGURE
15



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LEGEND

⊗ RID-102 WELL LOCATION

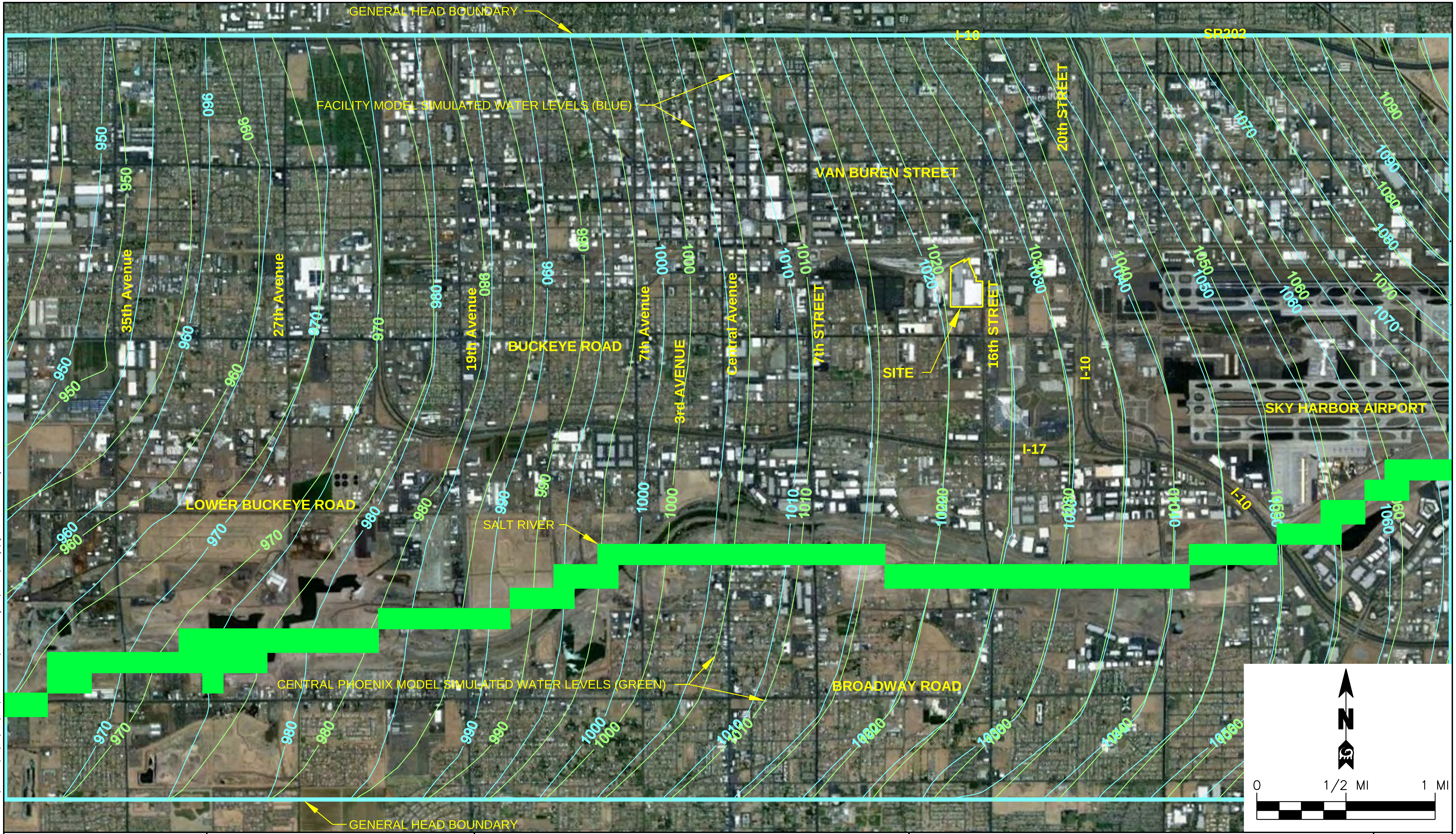
SIMULATED HYDRAULIC CONDUCTIVITY ZONATION IN MODEL LAYERS 1 AND 2

500 South 15th Street Facility

Phoenix, Arizona

FIGURE

16



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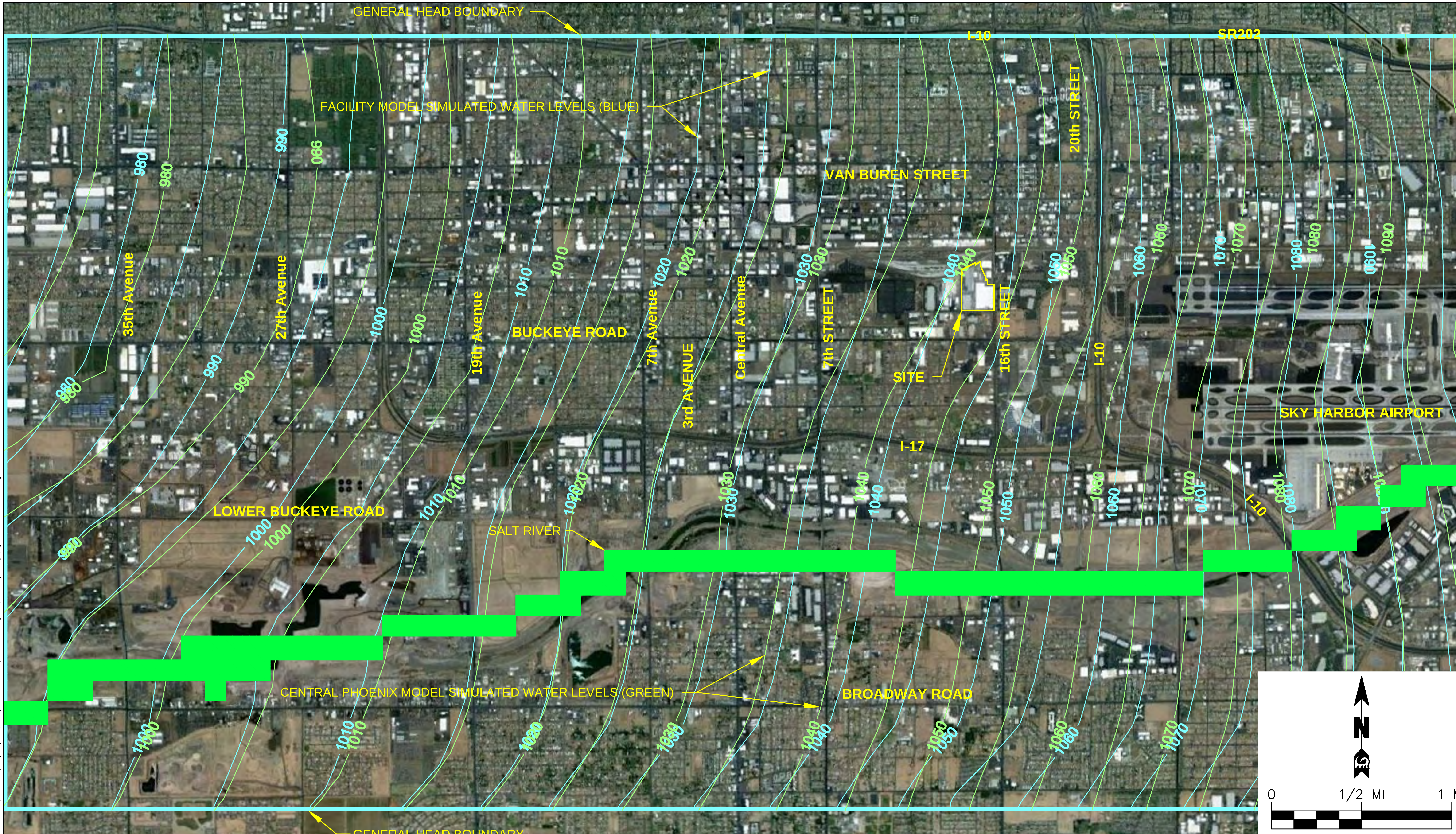
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED POTENTIOMETRIC MAPS (DECEMBER 1972)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
17A



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MODEL-SIMULATED POTENTIOMETRIC MAPS (FEBRUARY 1981)

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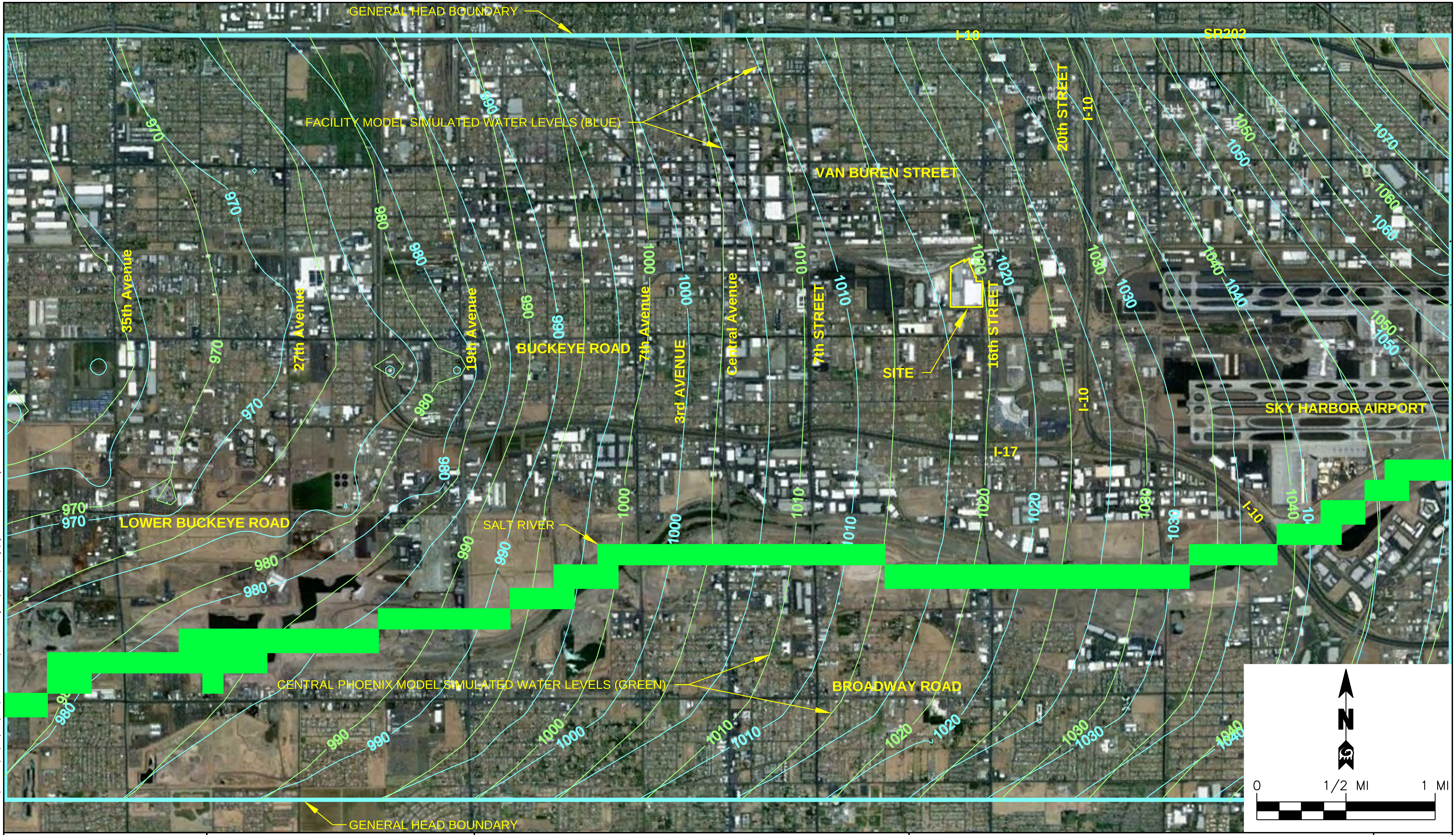
Phoenix, Arizona

FIGURE
17B



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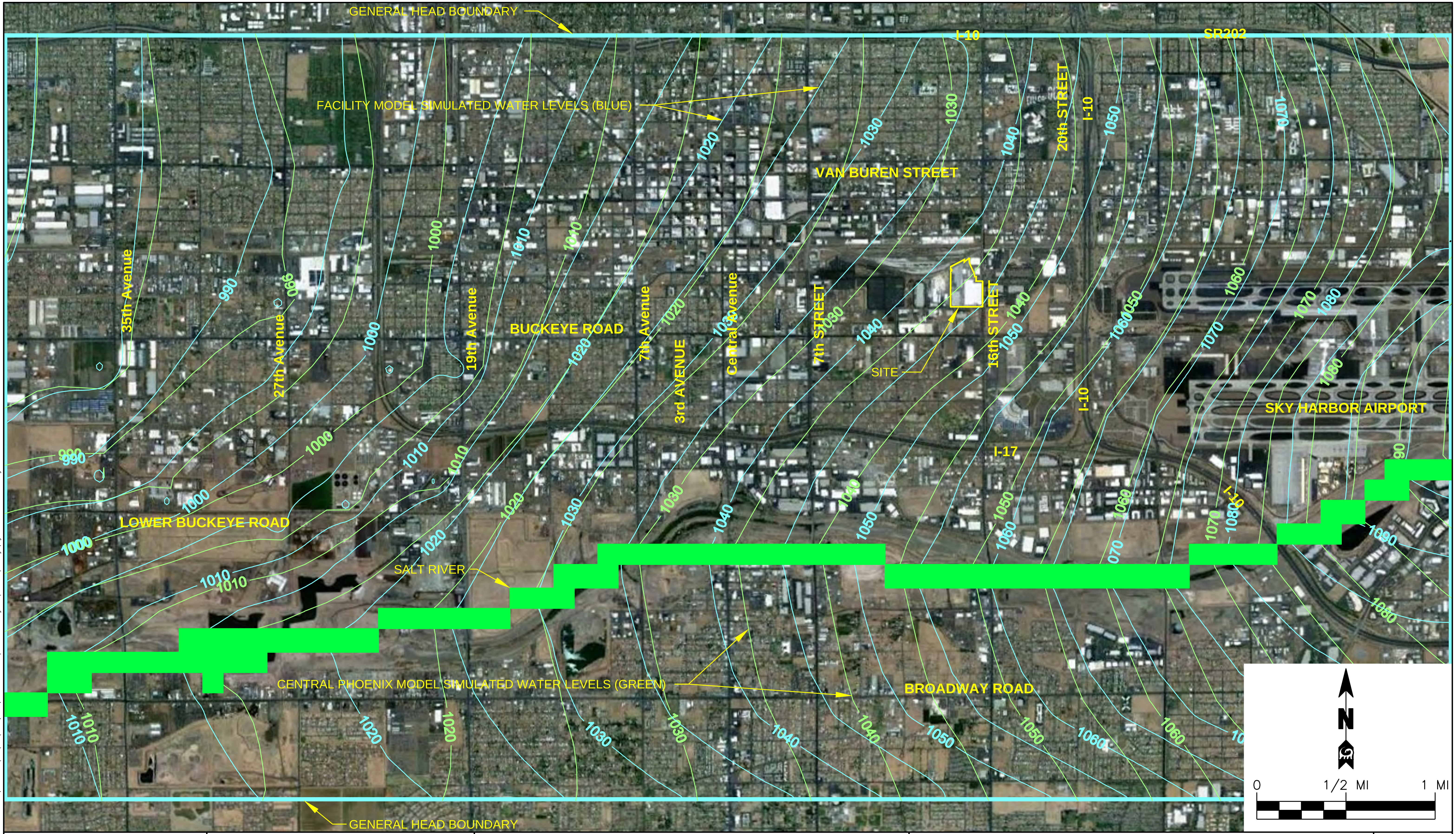
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED POTENTIOMETRIC MAPS (SEPTEMBER 1991)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
17C



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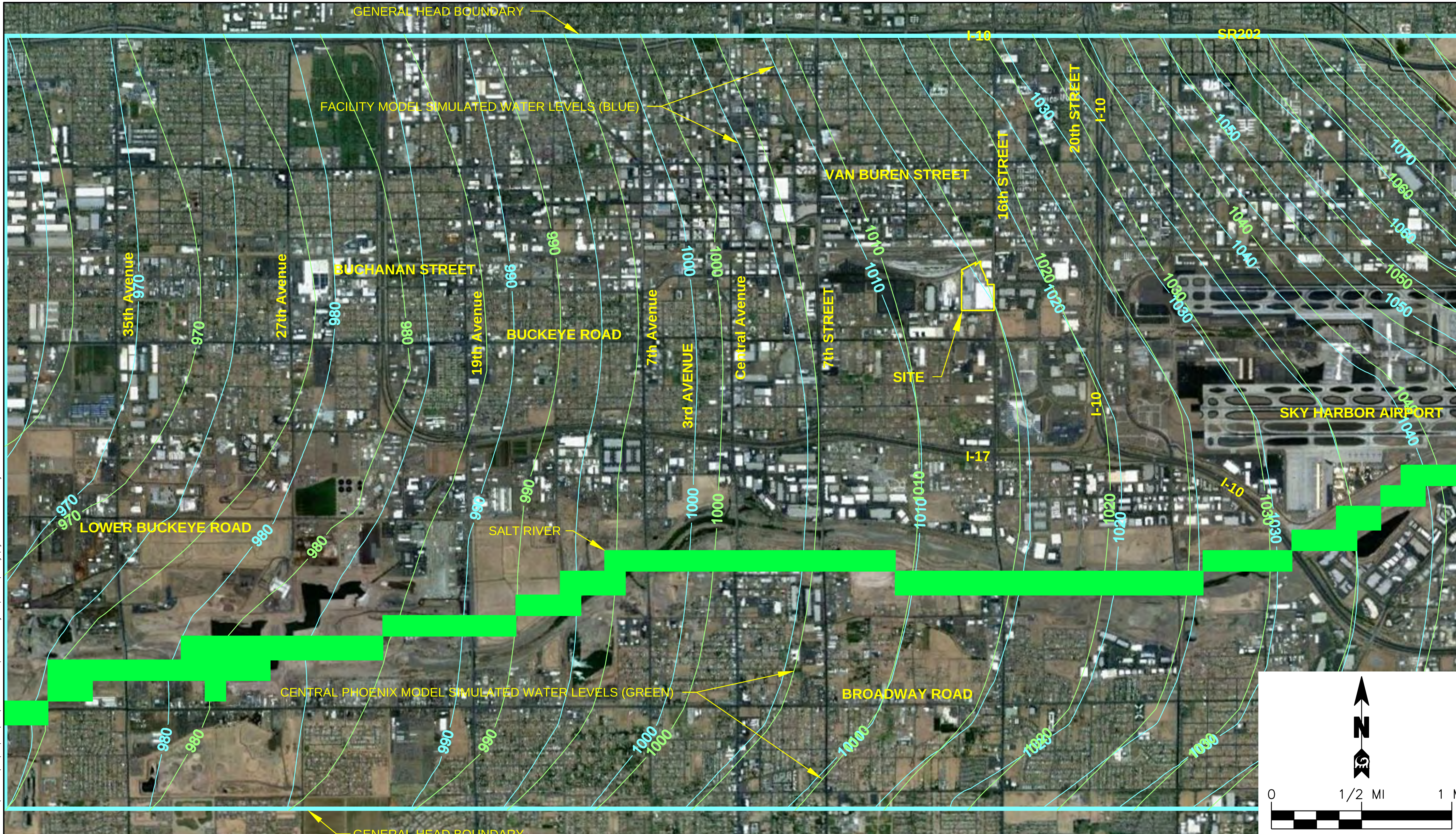
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED POTENTIOMETRIC MAPS (SEPTEMBER 1993)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE **17D**



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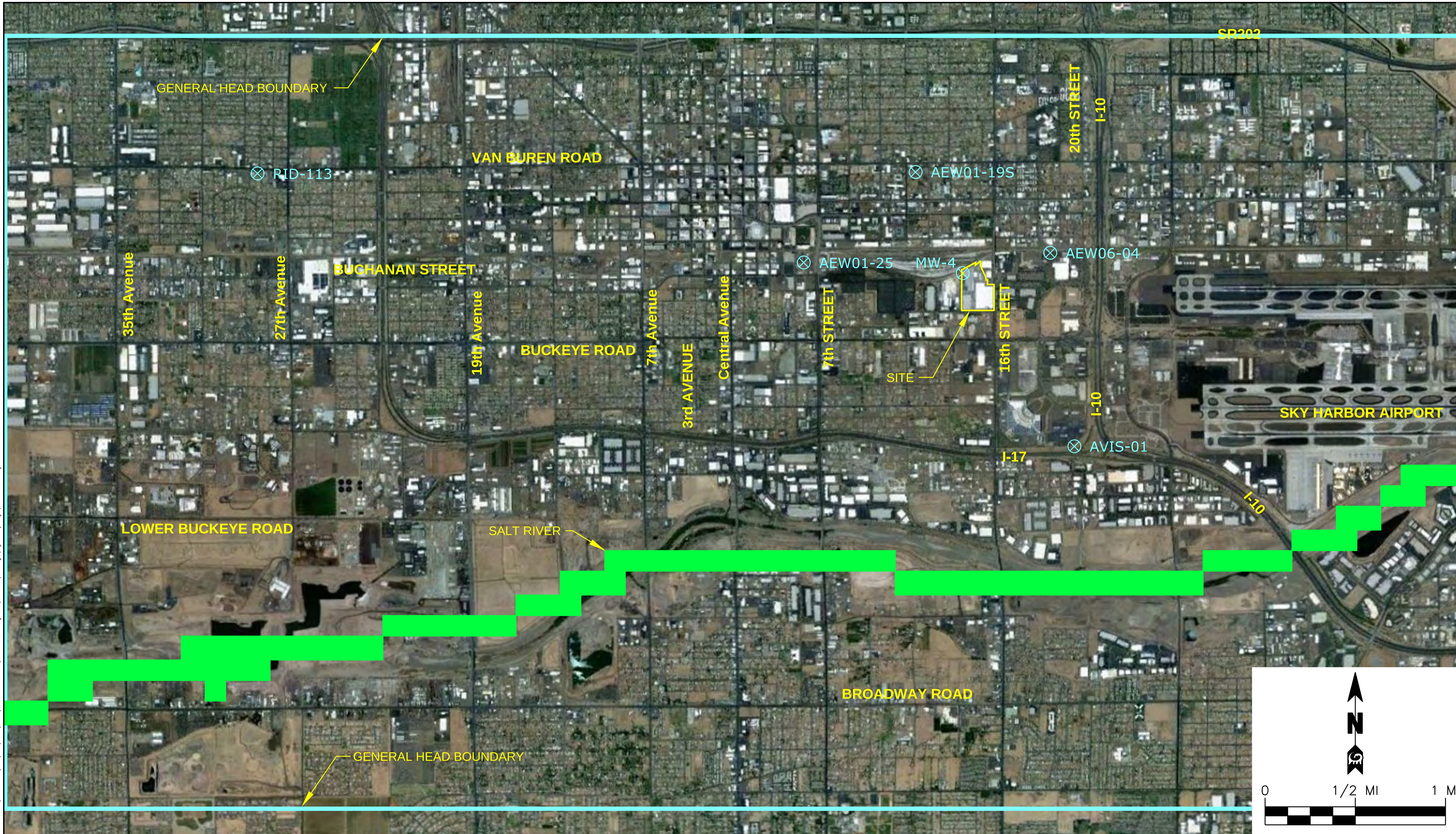
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED POTENTIOMETRIC MAPS (DECEMBER 1998)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
17E



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

⊗ RID-113 WELL LOCATION

HYDROGRAPH WELL LOCATIONS WITHIN THE FACILITY MODEL DOMAIN

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

18A

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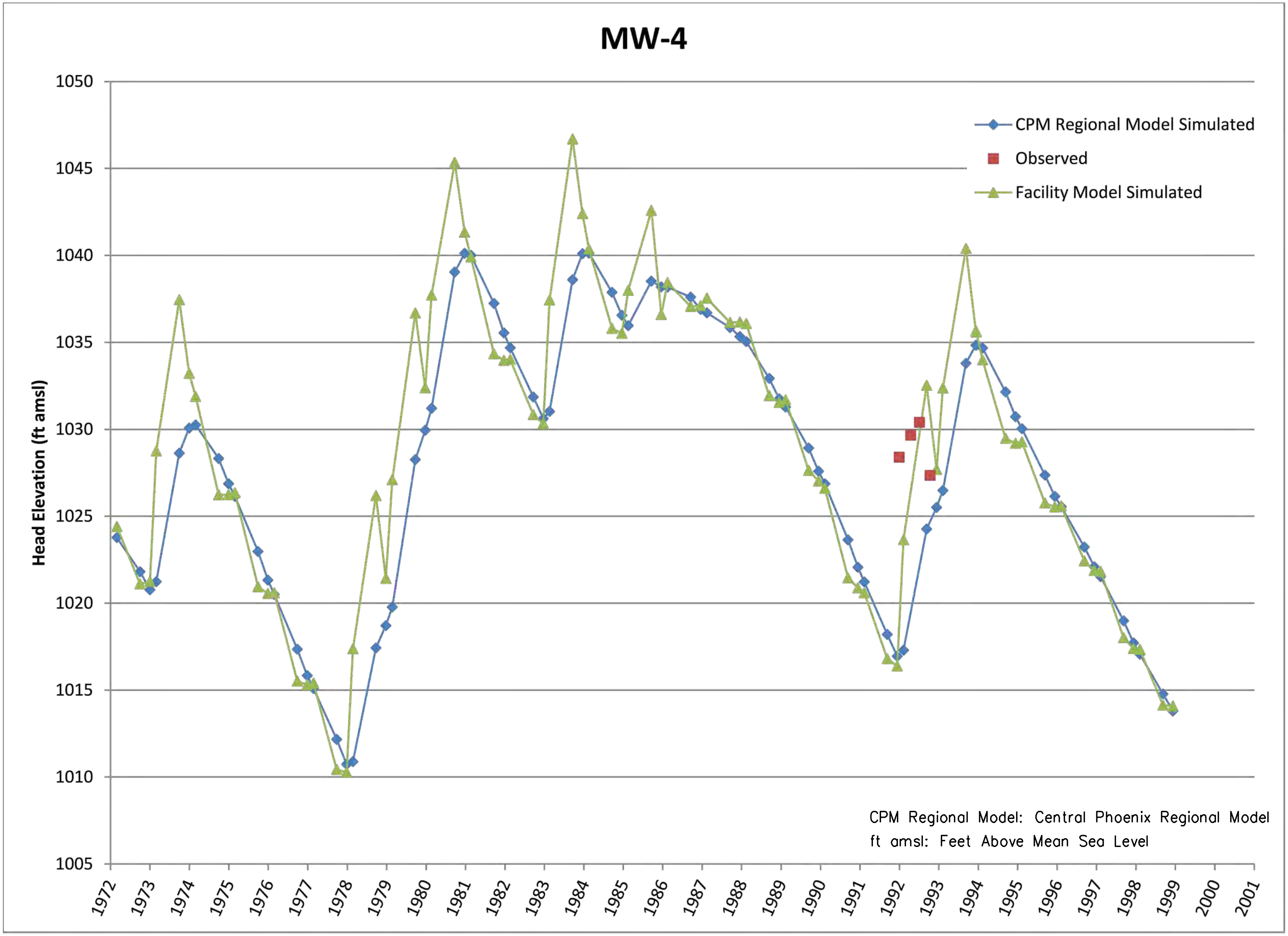

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HYDROGRAPH FOR MW-4

500 South 15th Street Facility
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FIGURE
18B

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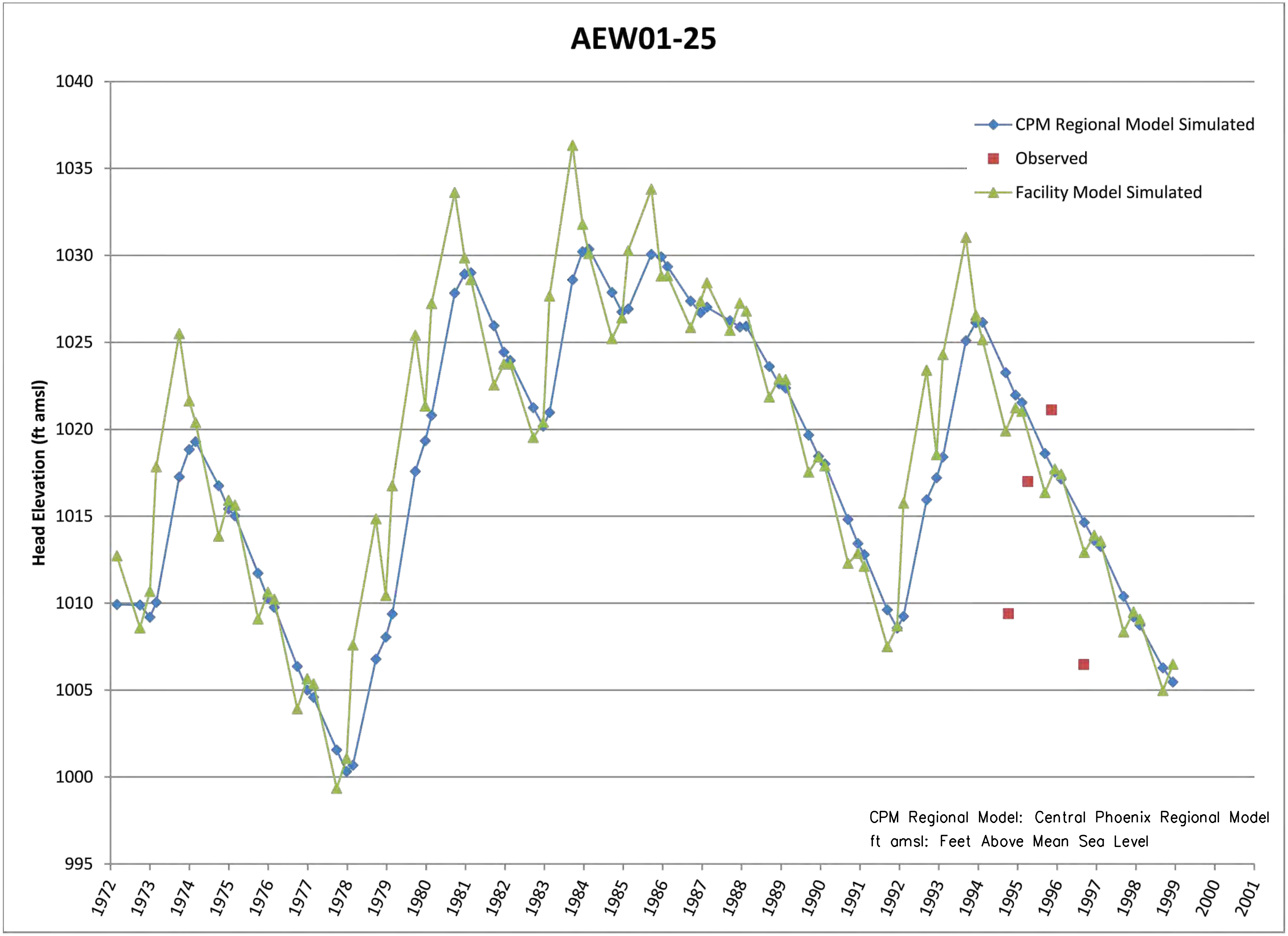

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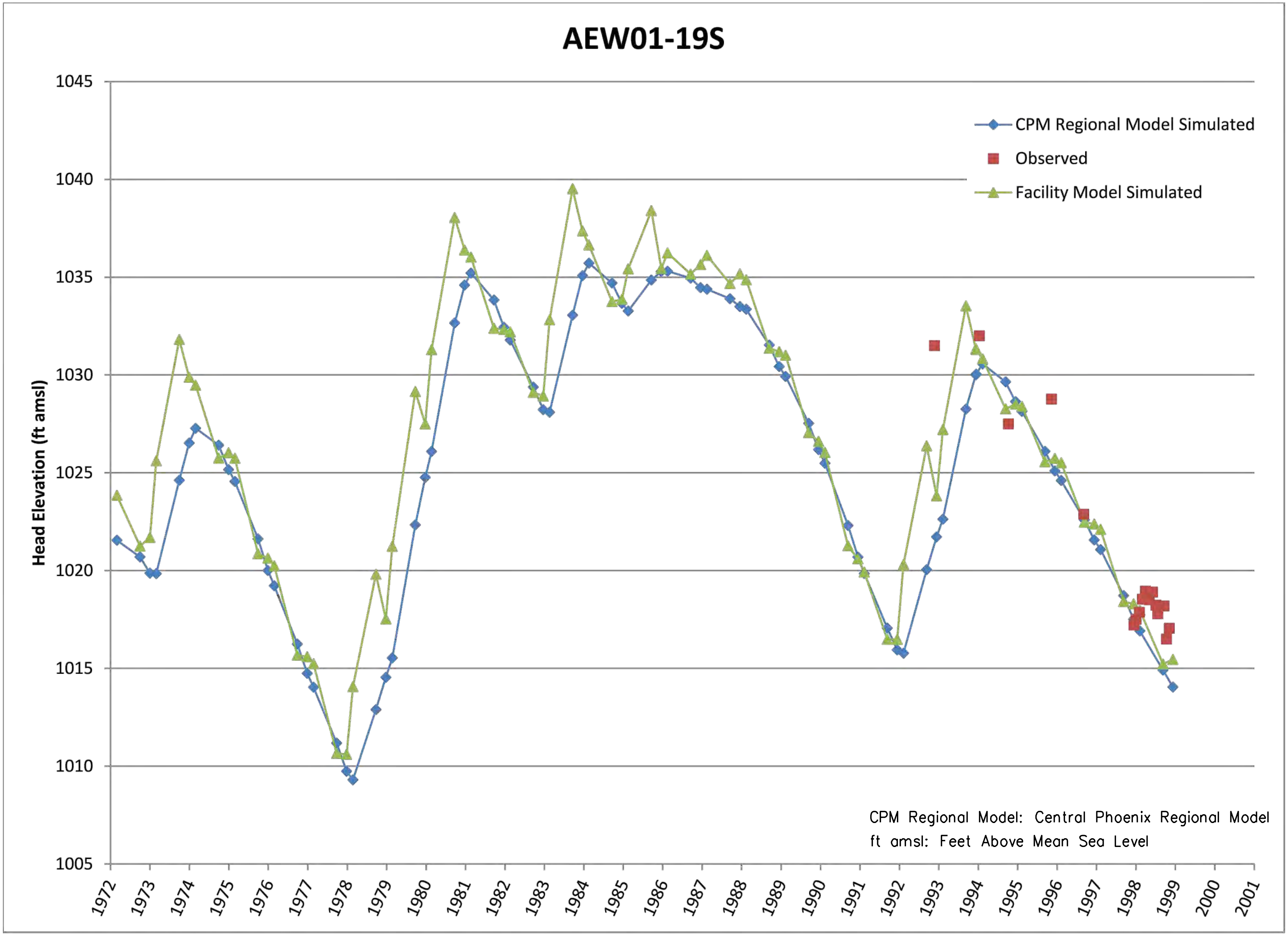
HYDROGRAPH FOR AEW01-25

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

18C



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HYDROGRAPH FOR AEW01-19S

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FIGURE

18D

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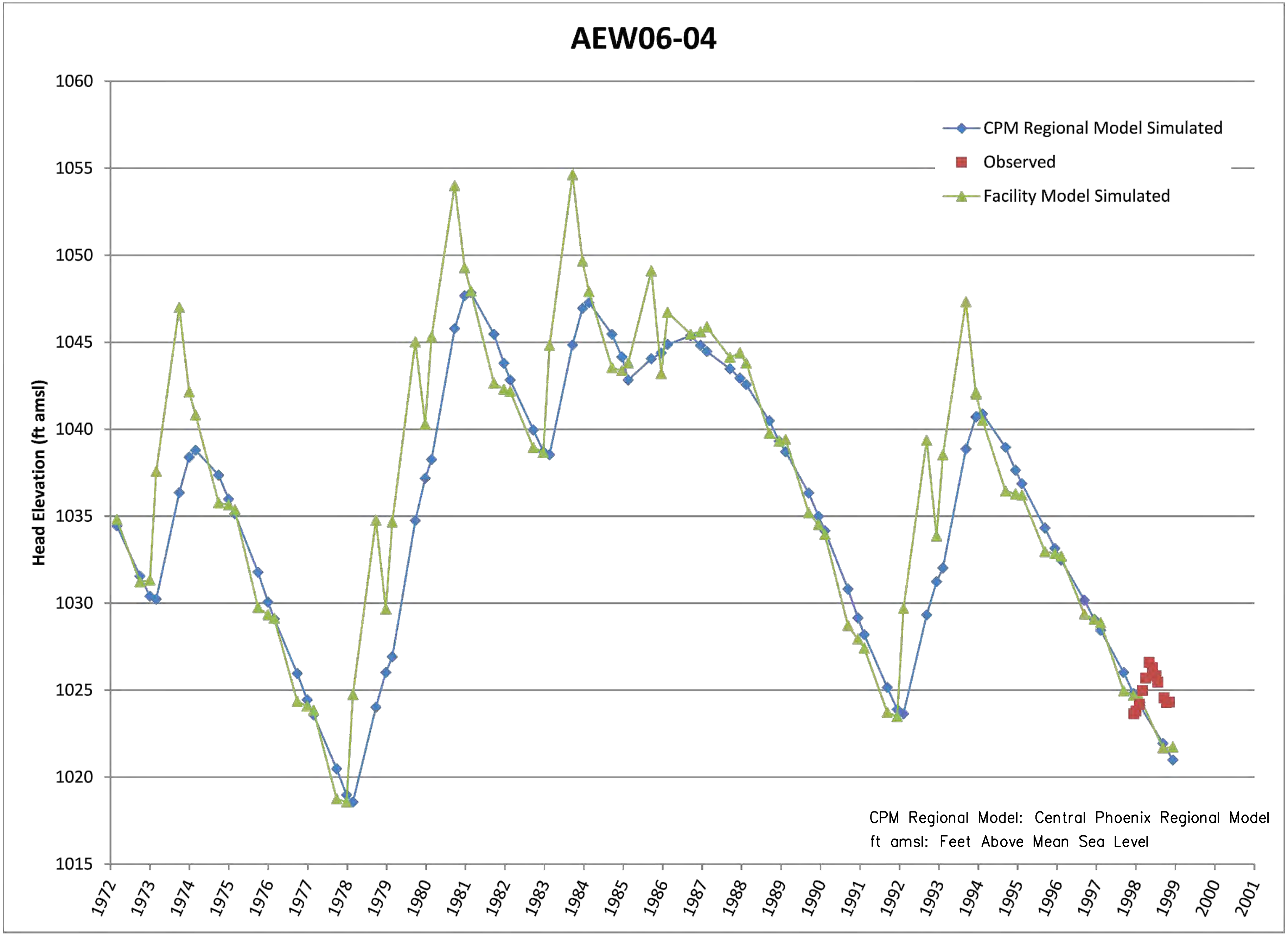

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HYDROGRAPH FOR AEW06-04

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FIGURE
18E

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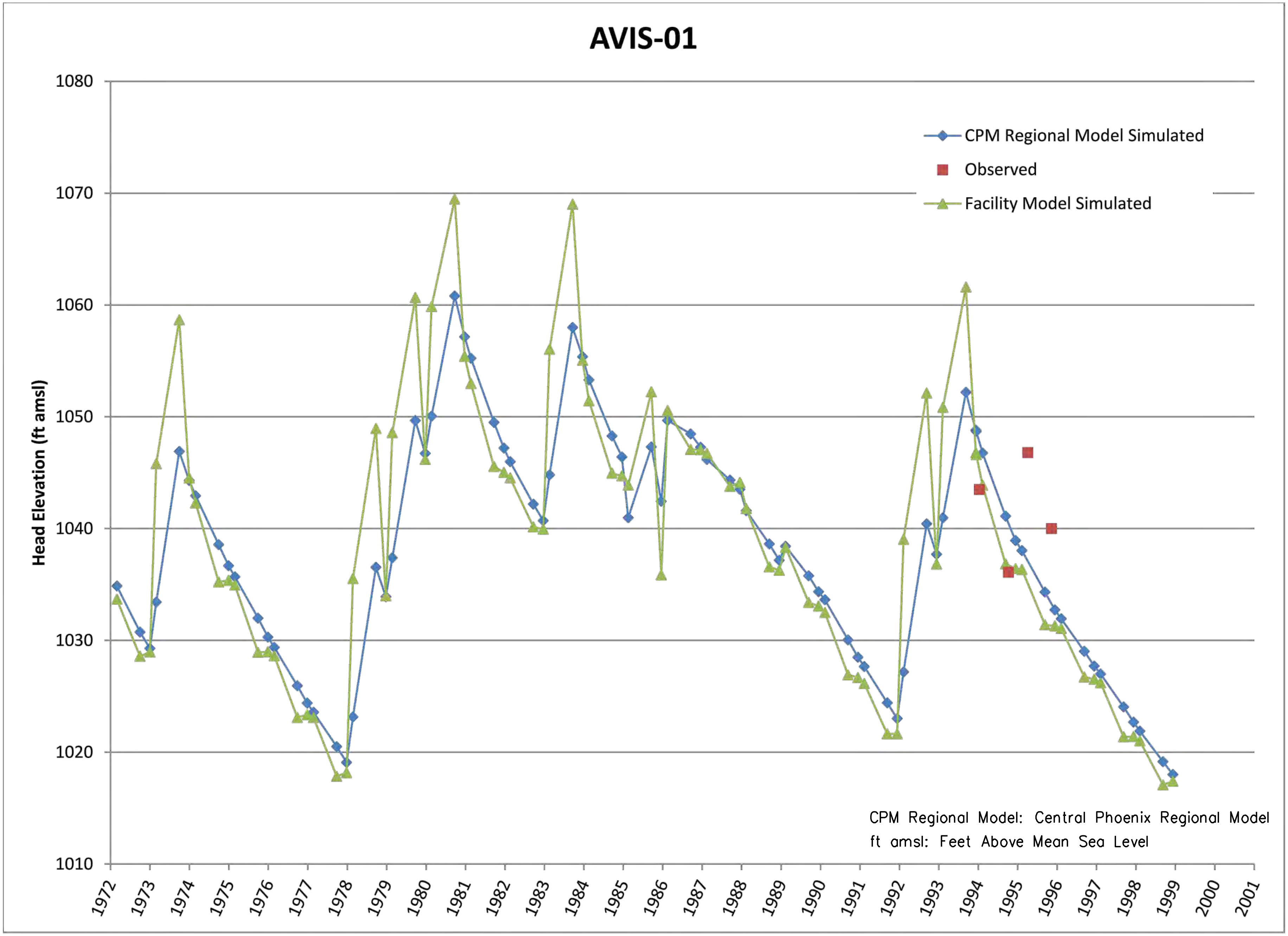

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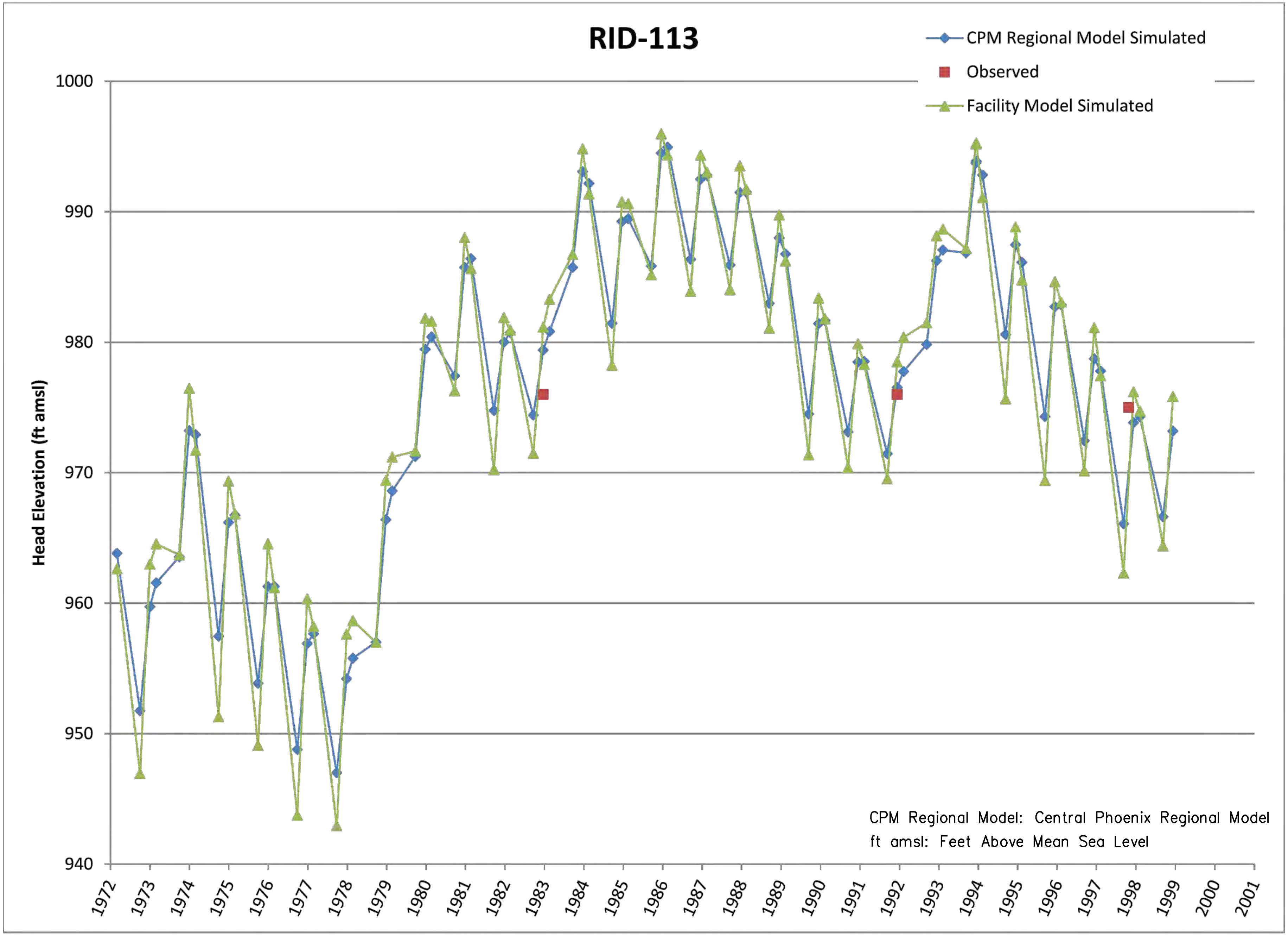
Groundwater Flow and Solute Transport Modeling Report

HYDROGRAPH FOR AVIS-01

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

18F



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HYDROGRAPH FOR RID-113

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

18G

Acad Version : R18.1s (LMS Tech)
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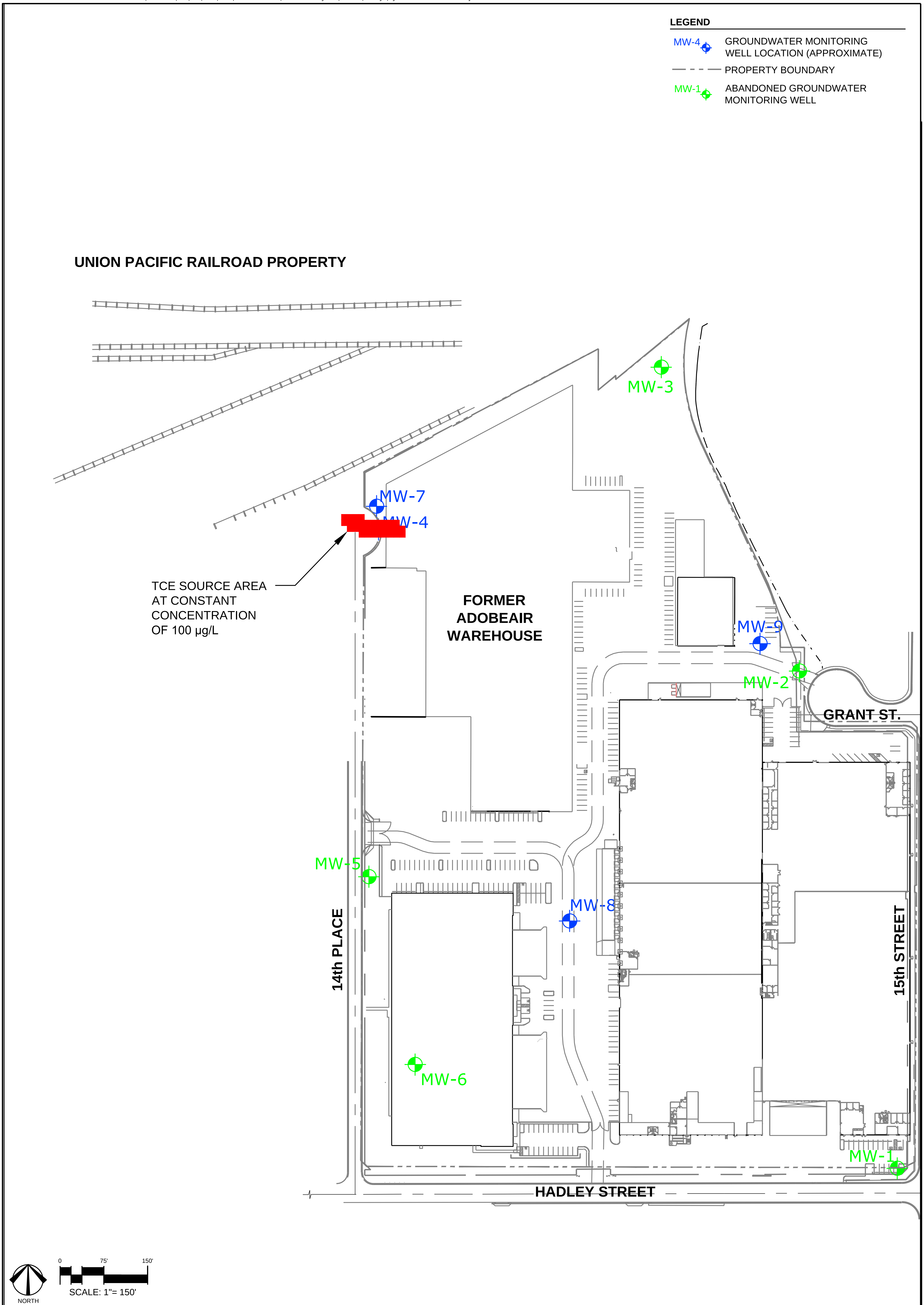
Date\Time : Wed, 23 Jan 2013 - 10:35am
Path\Name : G:\ENV\ENV\PROJ\1000\1042 ArvinMeritor\Soil Gas Investigation\Phase II\drawings\Fig19 Potential Source Area.dwg



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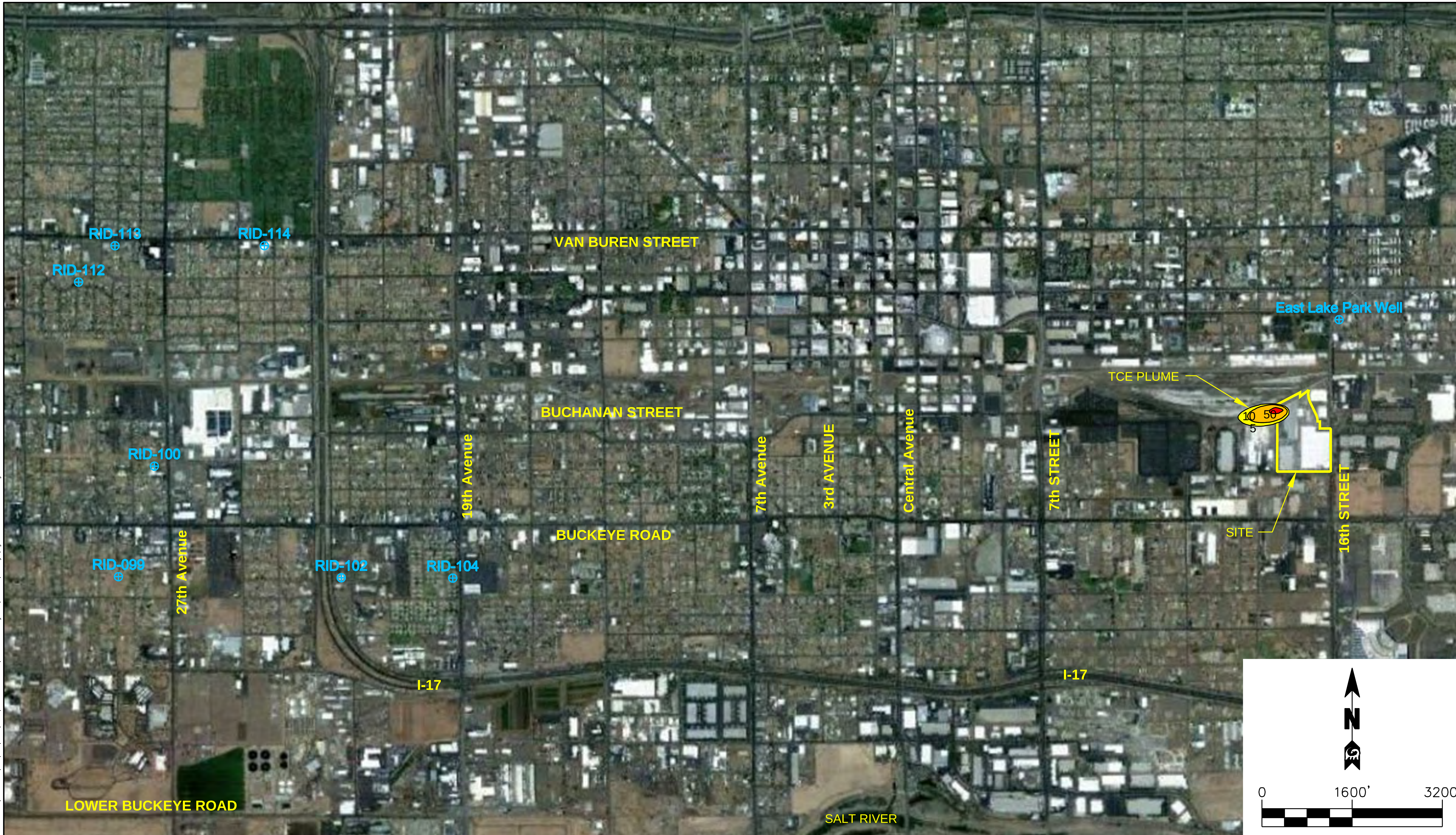
Groundwater Flow and Solute Transport Modeling Report

POTENTIAL SOURCE AREA APPLIED AT THE FACILITY

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
19



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LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (µg/L)

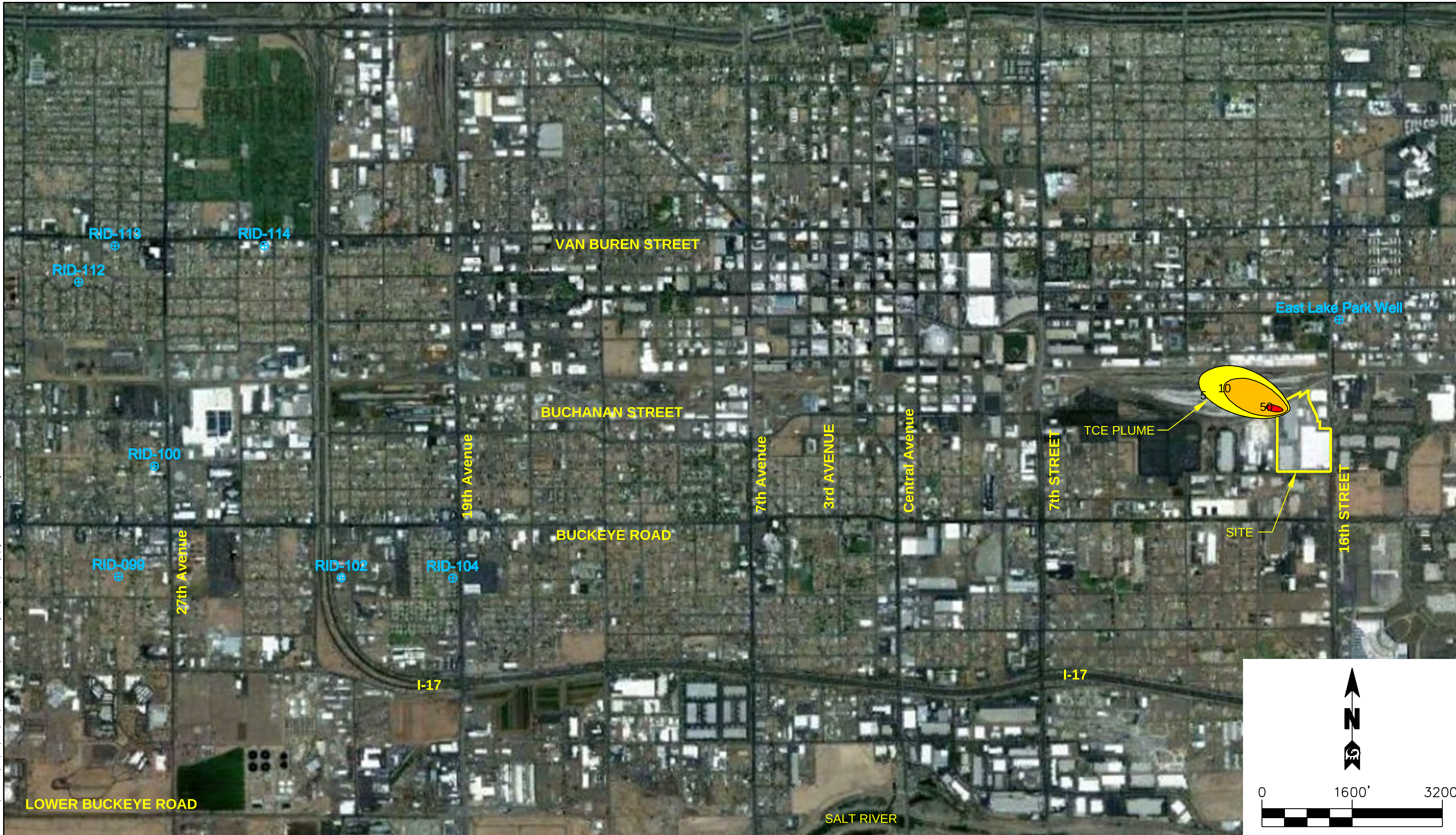
RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME EXTENT IN DECEMBER 1972

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

20A



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (µg/L)

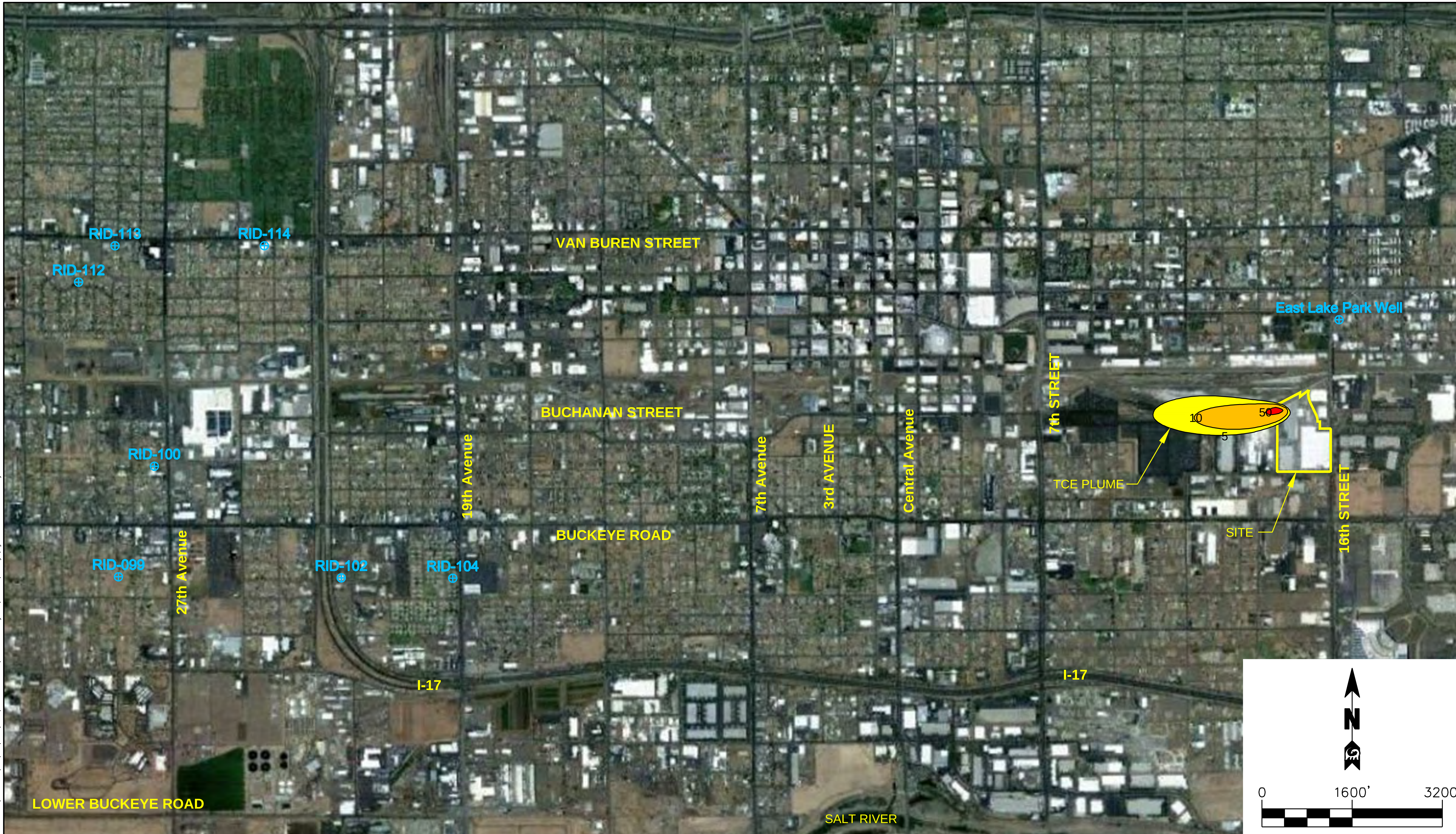
RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME EXTENT IN FEBRUARY 1981

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

20B



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (µg/L)

RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME EXTENT IN SEPTEMBER 1991

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
20C

Date\Time : Mon, 28 Jan 2013 - 3:52pm
Path\Name : G:\ENV\ENV\PROJ\1000\1042 ArvinMeritor\Soil Gas Investigation\Phase II\drawings\Fig20C TCE Plume 1991.dwg

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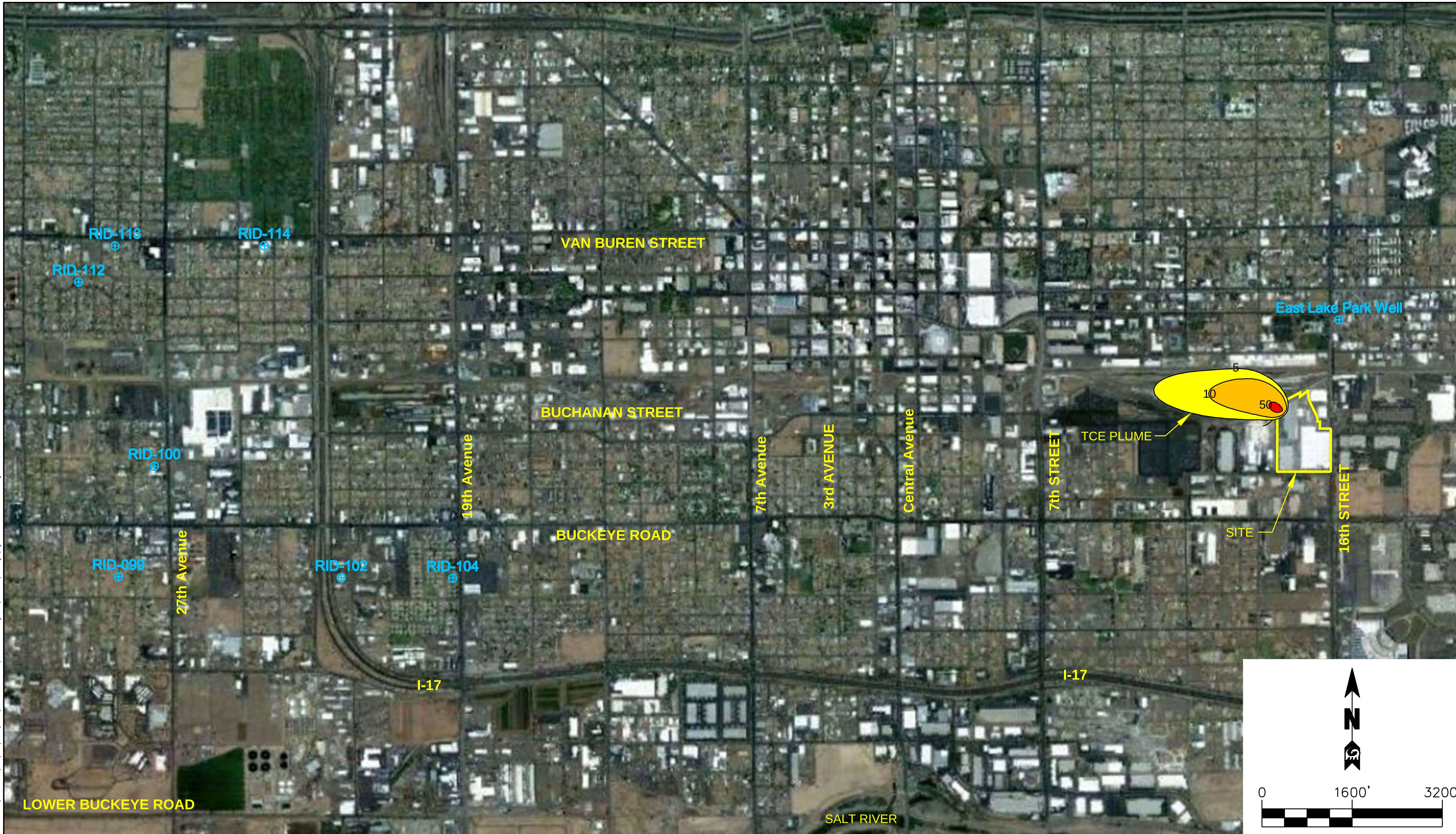

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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (μg/L)

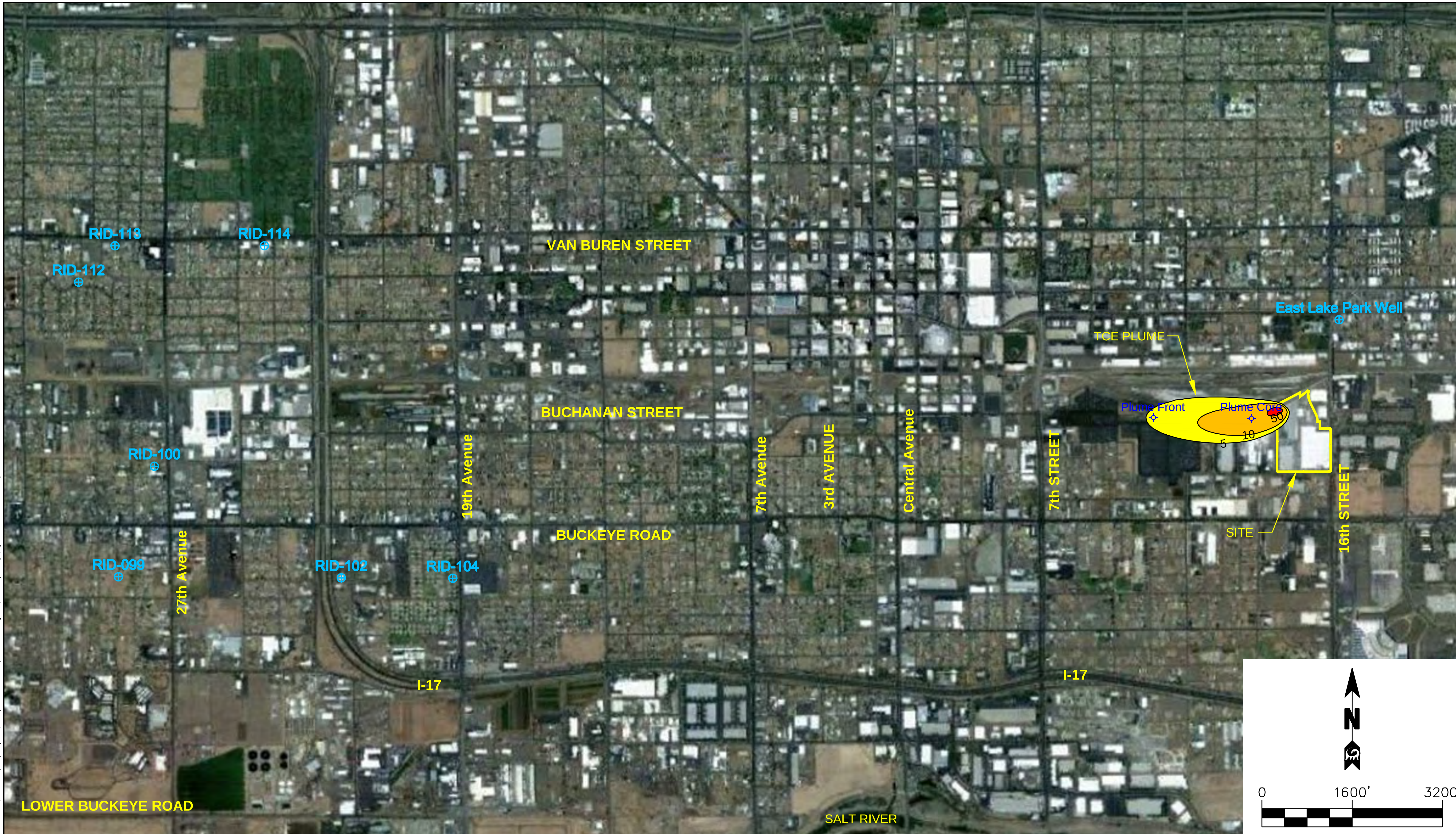
RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME EXTENT IN SEPTEMBER 1993

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

20D



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LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (µg/L)

RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME EXTENT IN DECEMBER 1998

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

20E

Acad Version : R18.1s (LMS Tech) Date\Time : Wed, 23 Jan 2013 - 1:28pm
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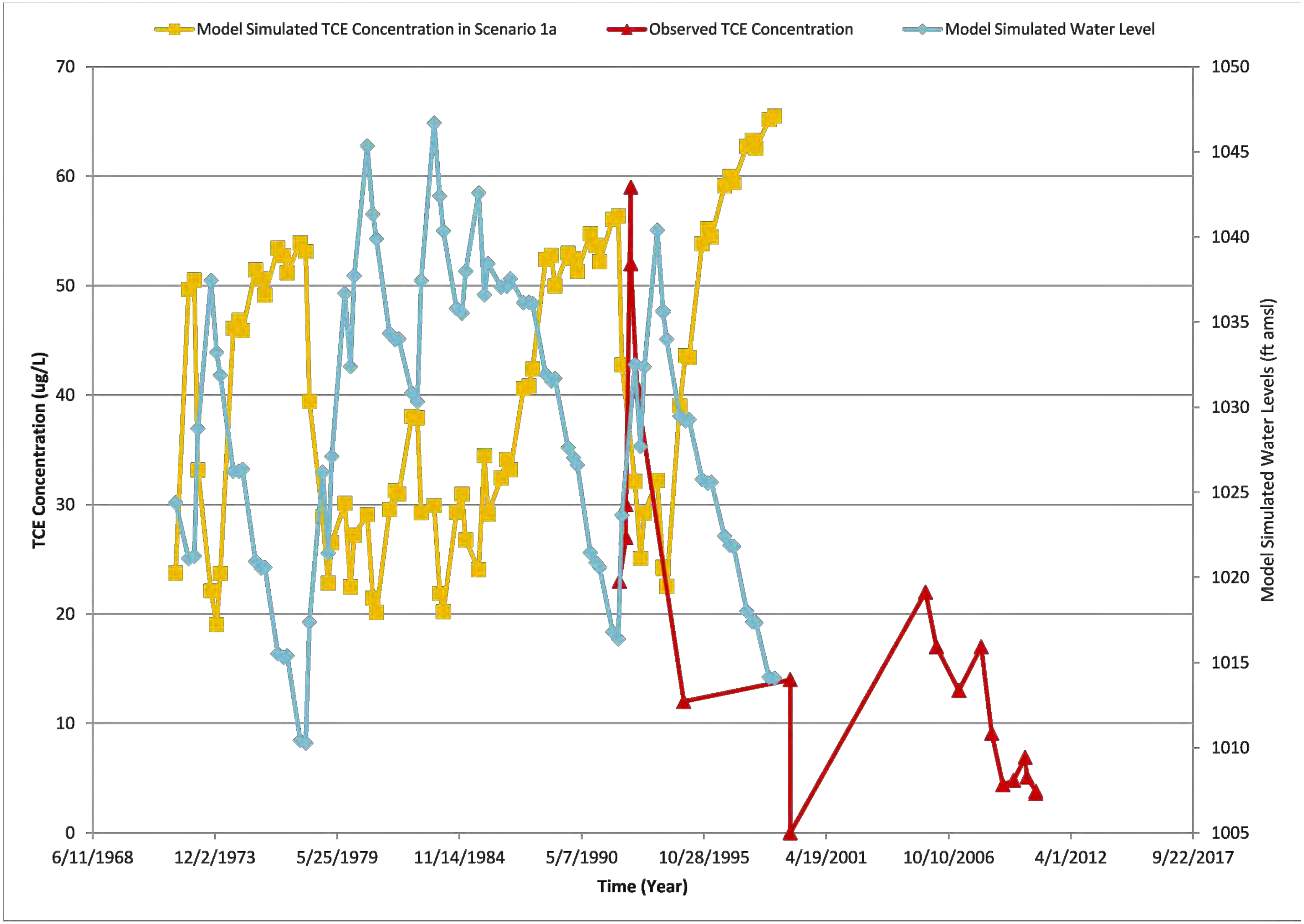

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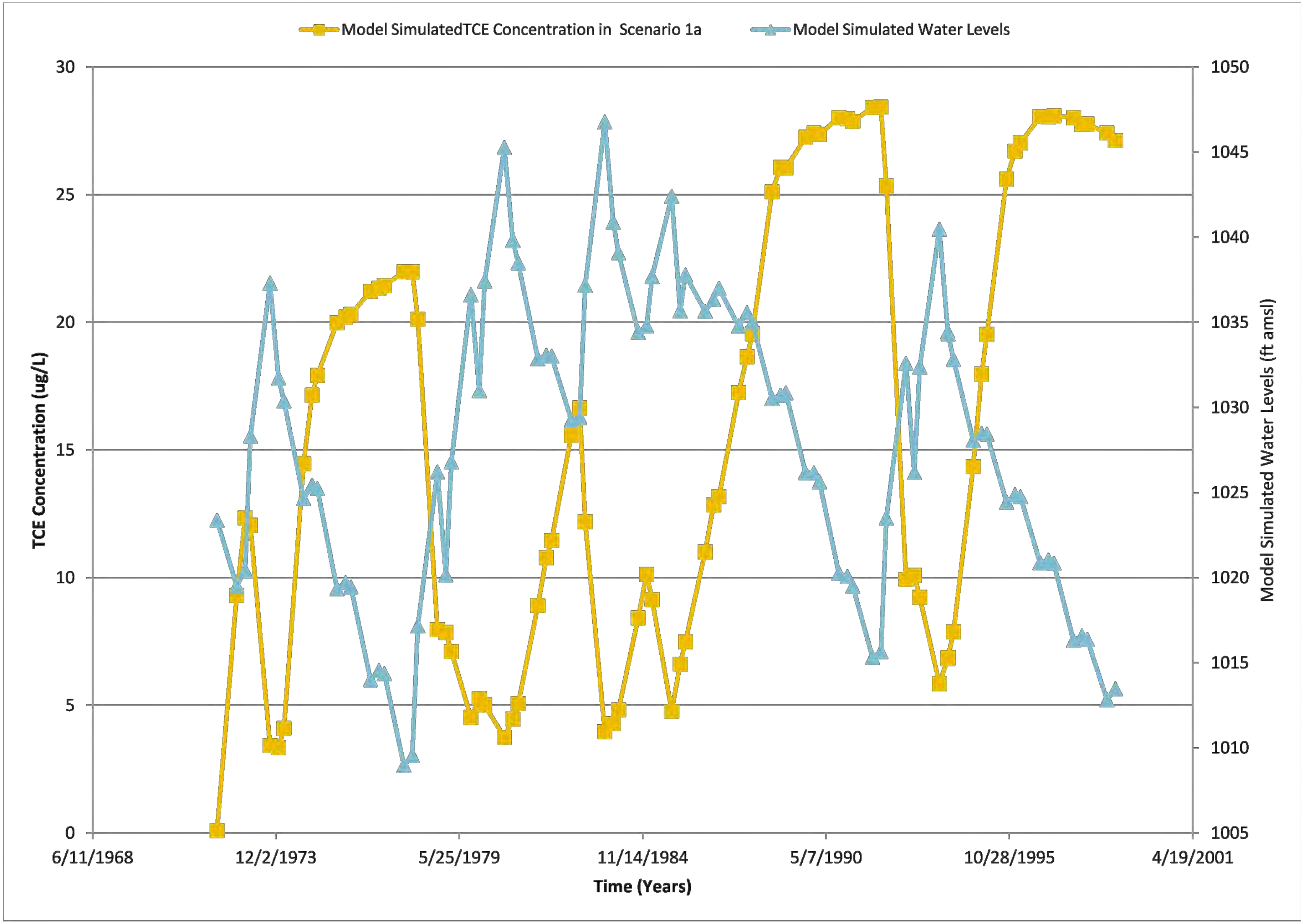
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED TCE CONCENTRATIONS OVER TIME AT MW-4 (SCENARIO 1a)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
21A

Acad Version : R18.1s (LMS Tech) Date\Time : Wed, 23 Jan 2013 - 1:28pm
User Name : RKosciolek Path\Name : G:\ENV\ENV\PROJ\1000\1042 ArvinMeritor\Soil Gas Investigation\Phase II\drawings\Fig21ABC TCE Concen.dwg



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Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED TCE CONCENTRATIONS OVER TIME AT THE PLUME CORE TARGET (SCENARIO 1a)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
21B

Acad Version : R18.1s (LMS Tech) Date\Time : Wed, 23 Jan 2013 - 1:29pm
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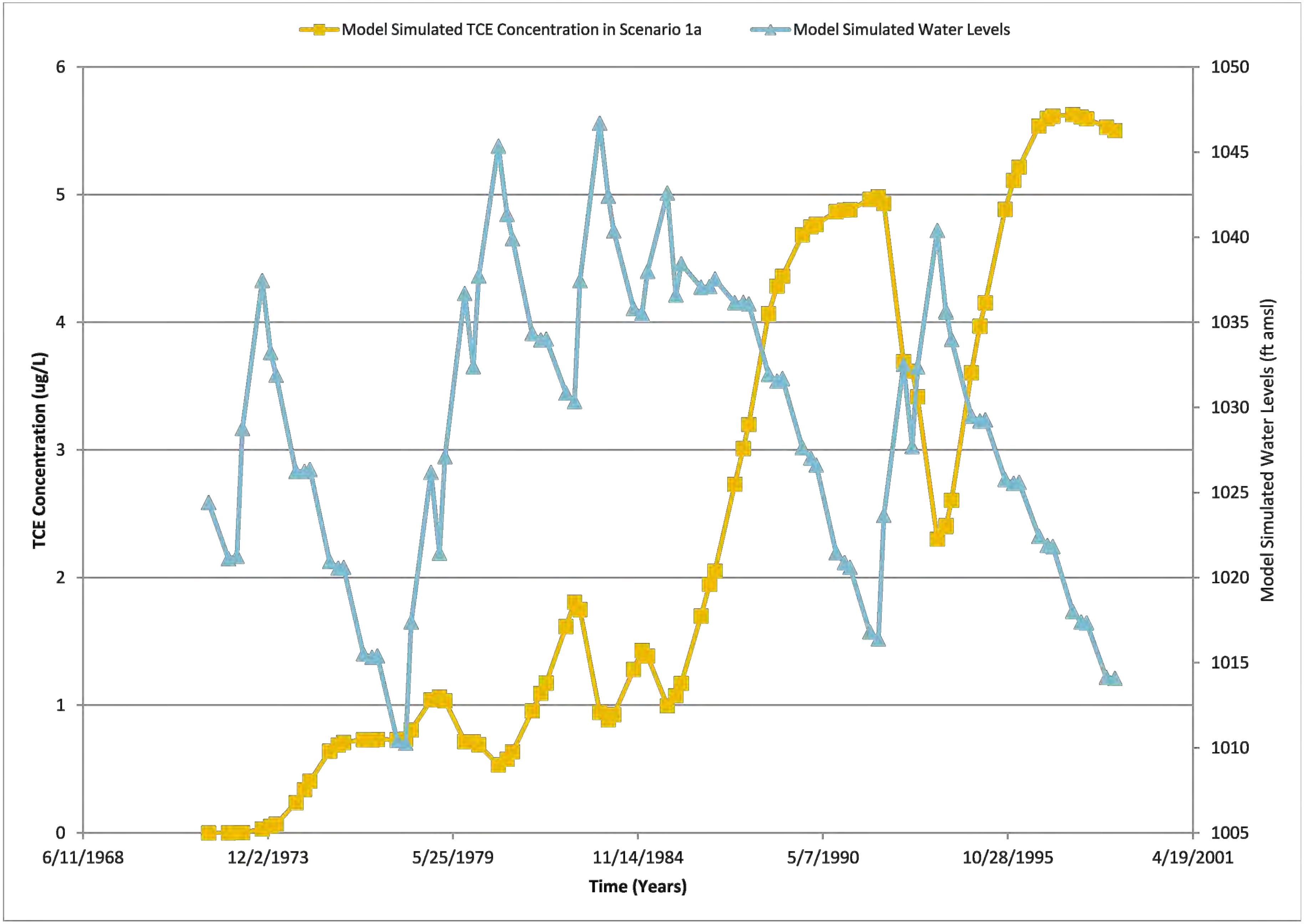

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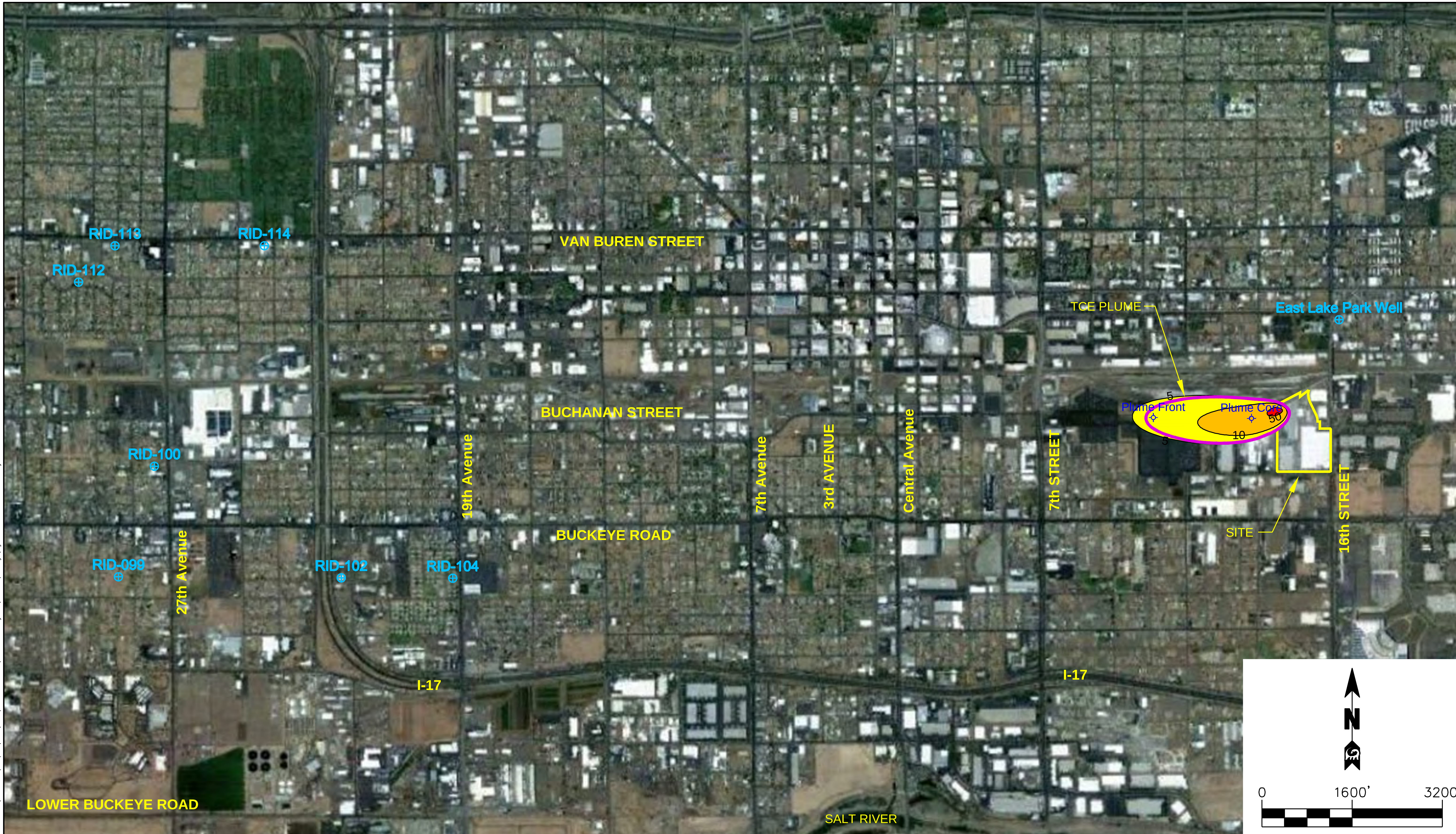
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED TCE CONCENTRATIONS OVER TIME AT THE PLUME FRONT TARGET (SCENARIO 1a)
500 South 15th Street Facility
Phoenix, Arizona

FIGURE
21C



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER ($\mu g/L$)

MODEL-SIMULATED TCE PLUME EXTENT IN 1998 in Scenario 1a – BASE CASE

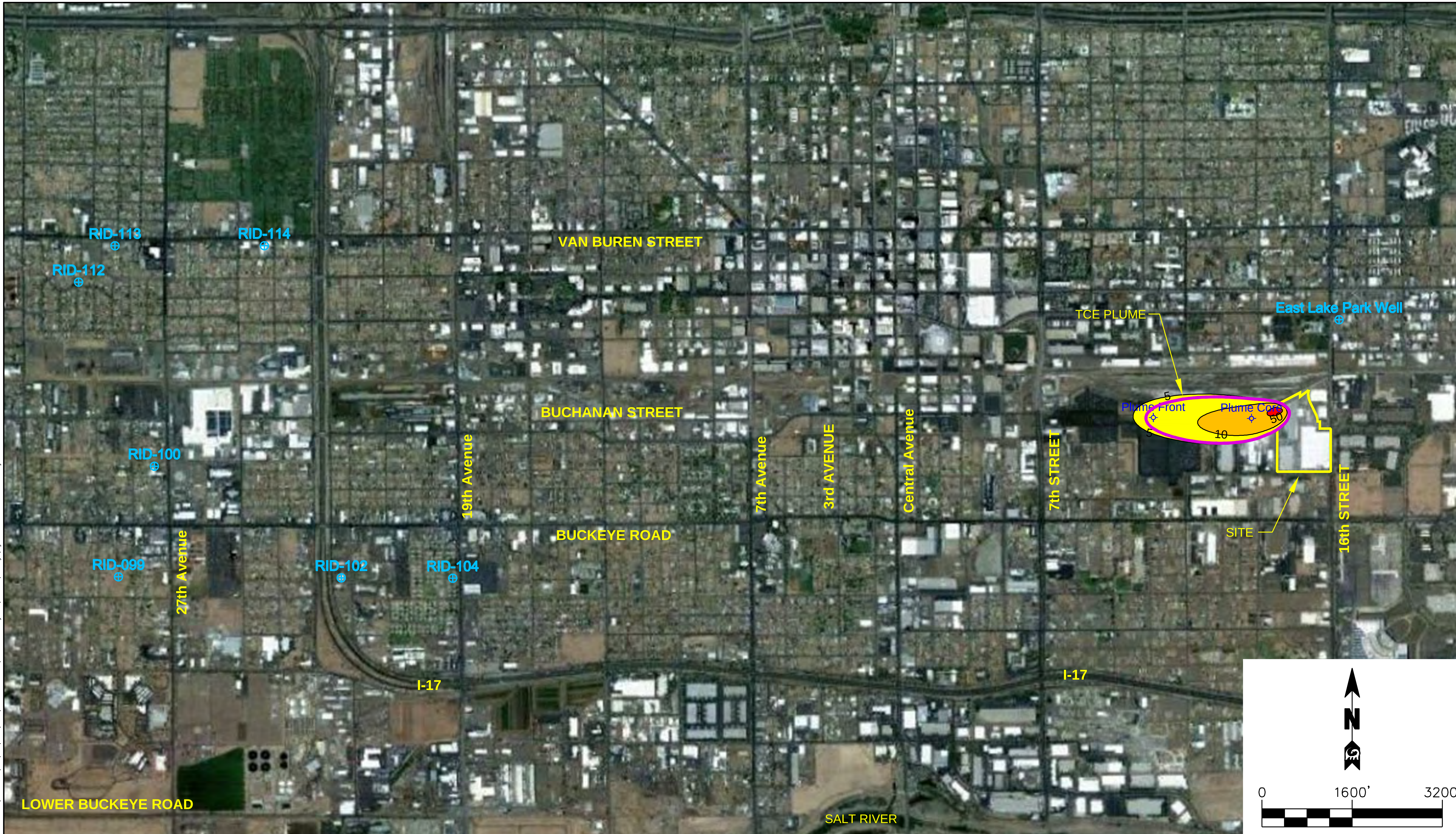
RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME IN 1998 (SCENARIO 1b)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
22A

Acad Version : R18.1s (LMS Tech) User Name : RKoscielek Date\Time : Mon, 28 Jan 2013 - 3:55pm Path\Name : G:\ENV\ENV\PROJ\1000\1042 ArvinMeritor\Soil Gas Investigation\Phase II\drawings\Fig22A TCE Concen 1998 1b.dwg



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 / 10 / 50	PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (µg/L)
	MODEL-SIMULATED TCE PLUME EXTENT IN 1998 in Scenario 1a – BASE CASE
RID-102 ⊕	WELL LOCATION

MODEL-SIMULATED TCE PLUME IN 1998 (SCENARIO 1c)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE **22B**

Acad Version : R18.1s (LMS Tech)
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Date\Time : Mon, 28 Jan 2013 – 3:56pm
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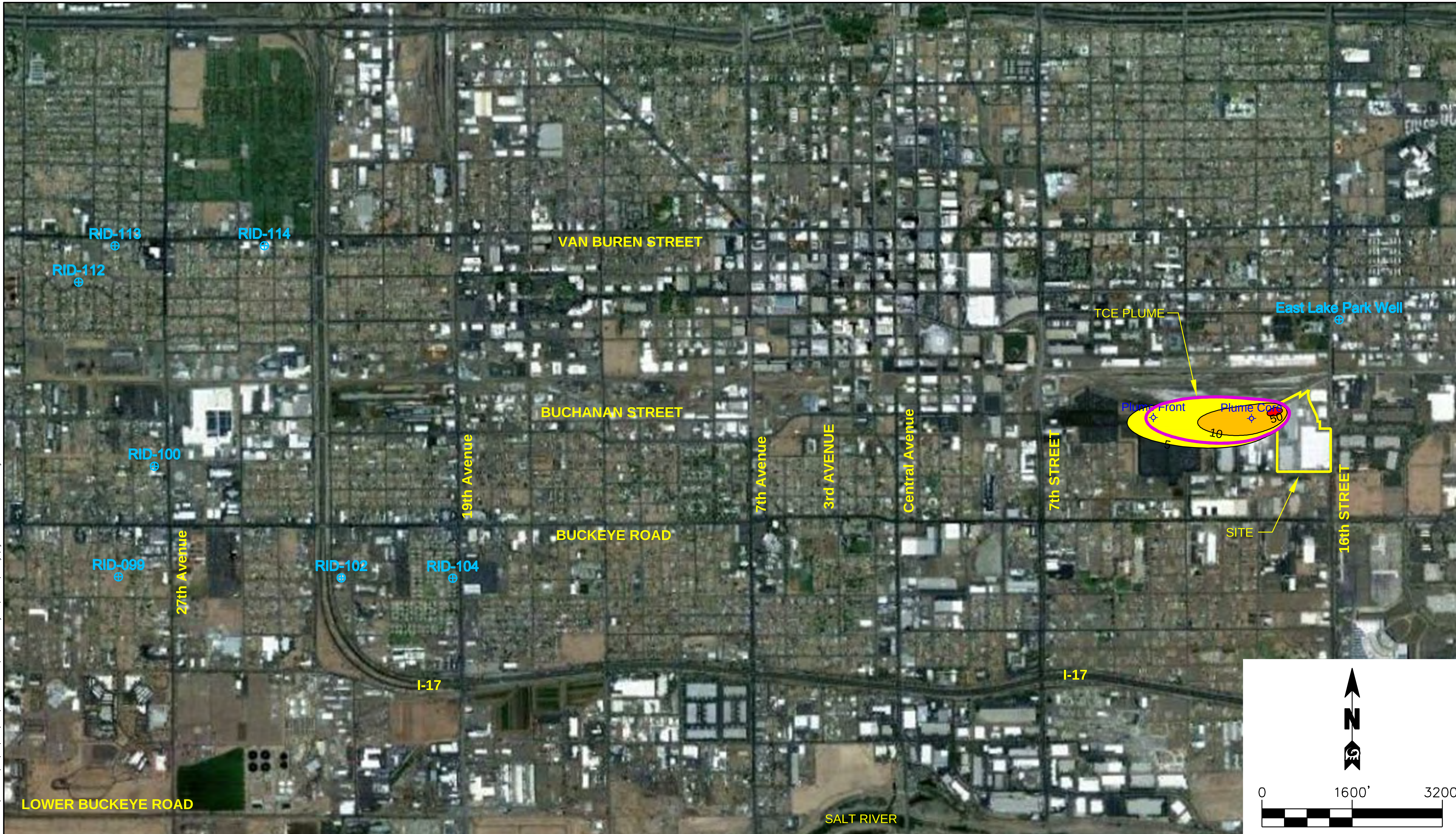

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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 10 50 PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (μg/L)

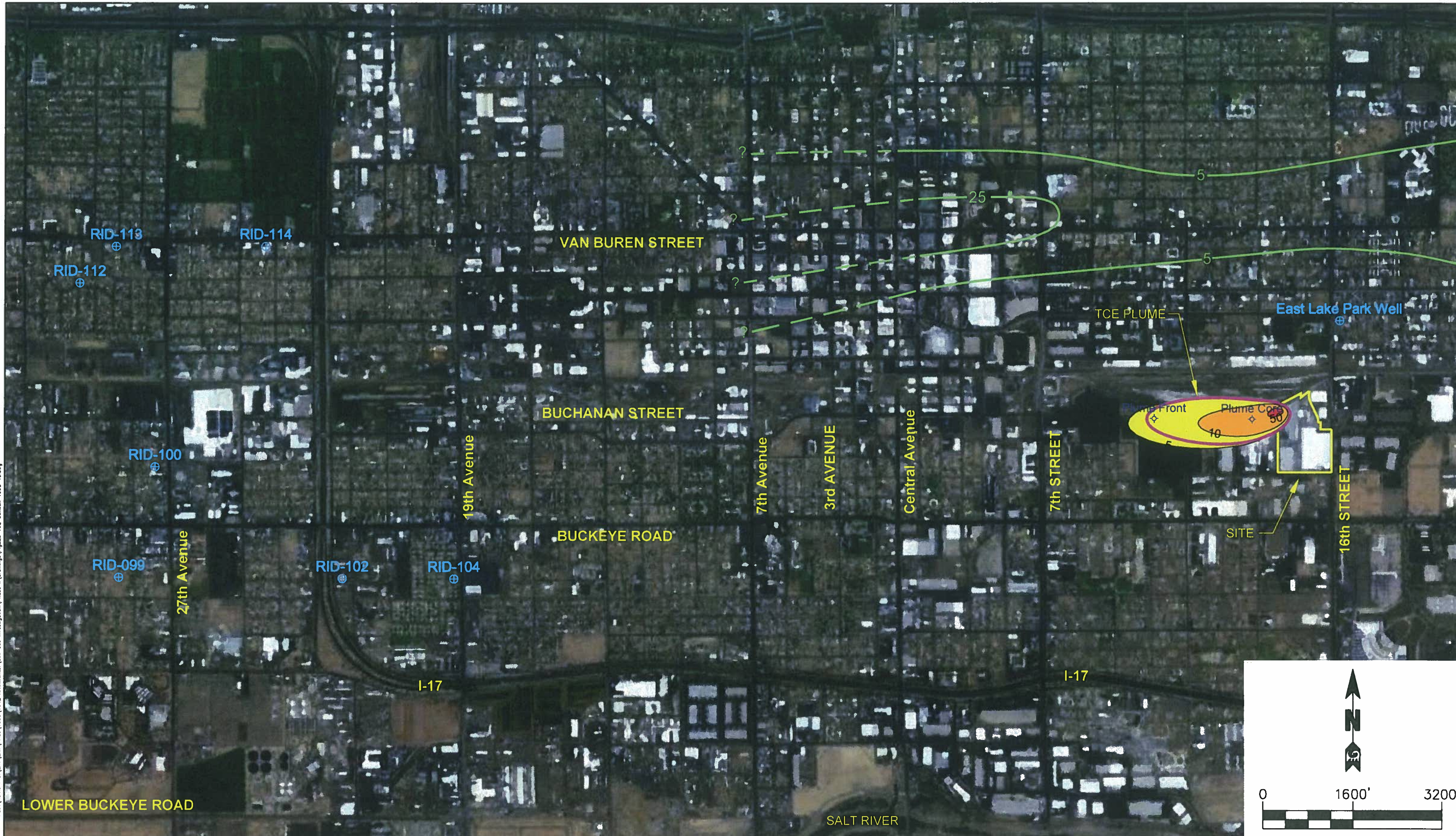
MODEL-SIMULATED TCE PLUME EXTENT IN 1998 in Scenario 1a – BASE CASE

RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME IN 1998 (SCENARIO 1d)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
22C



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5 — MARCH 2011 OU3 TCE PLUME CONTOURS (ERM 2012)

5, 10, 50 — PLUME CONCENTRATIONS IN MICROGRAMS PER LITER (μg/L)

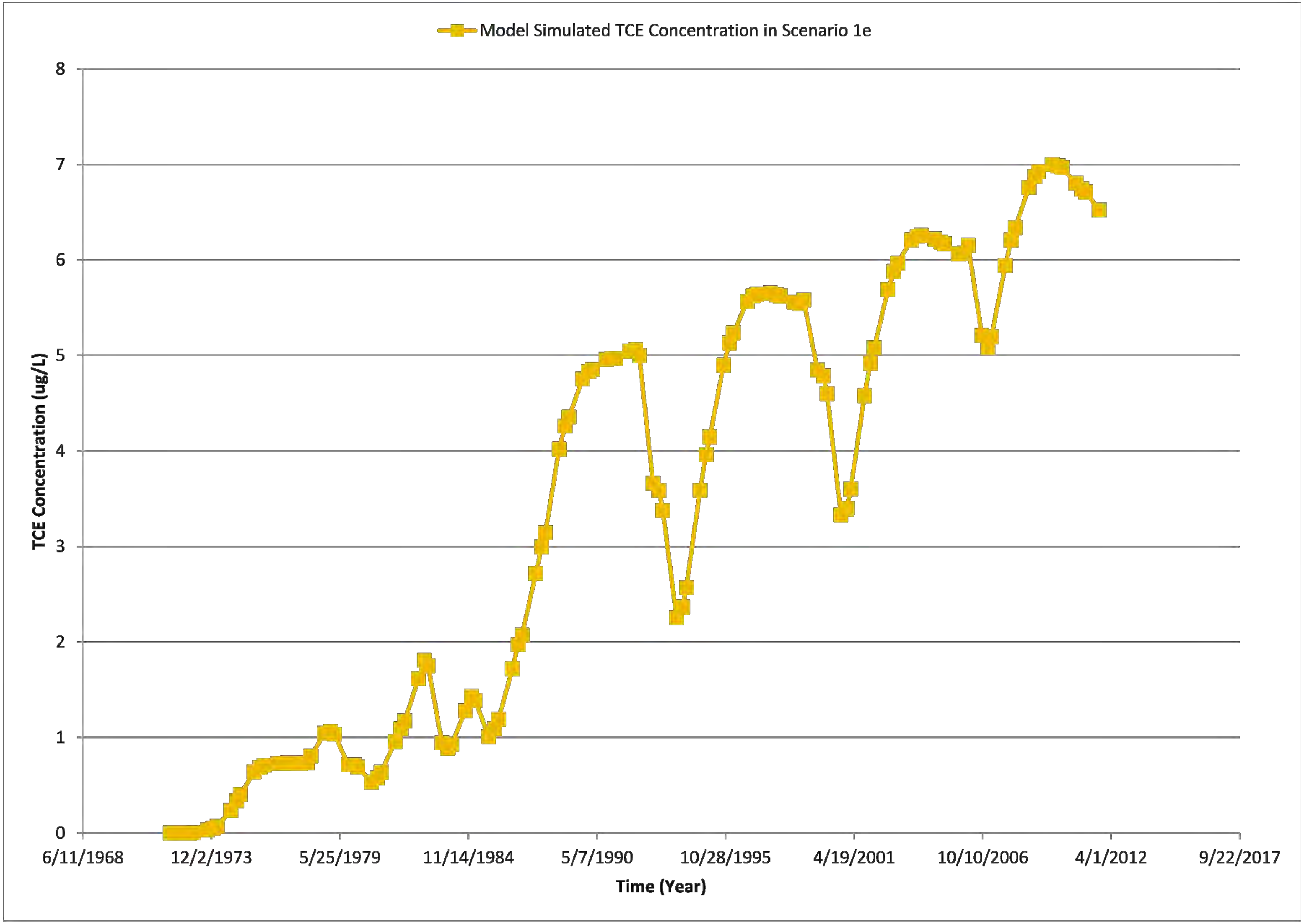
MODEL-SIMULATED TCE PLUME EXTENT IN 1998 in Scenario 1a – BASE CASE

RID-102 ⊕ WELL LOCATION

MODEL-SIMULATED TCE PLUME IN 2011 (SCENARIO 1e)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
22D



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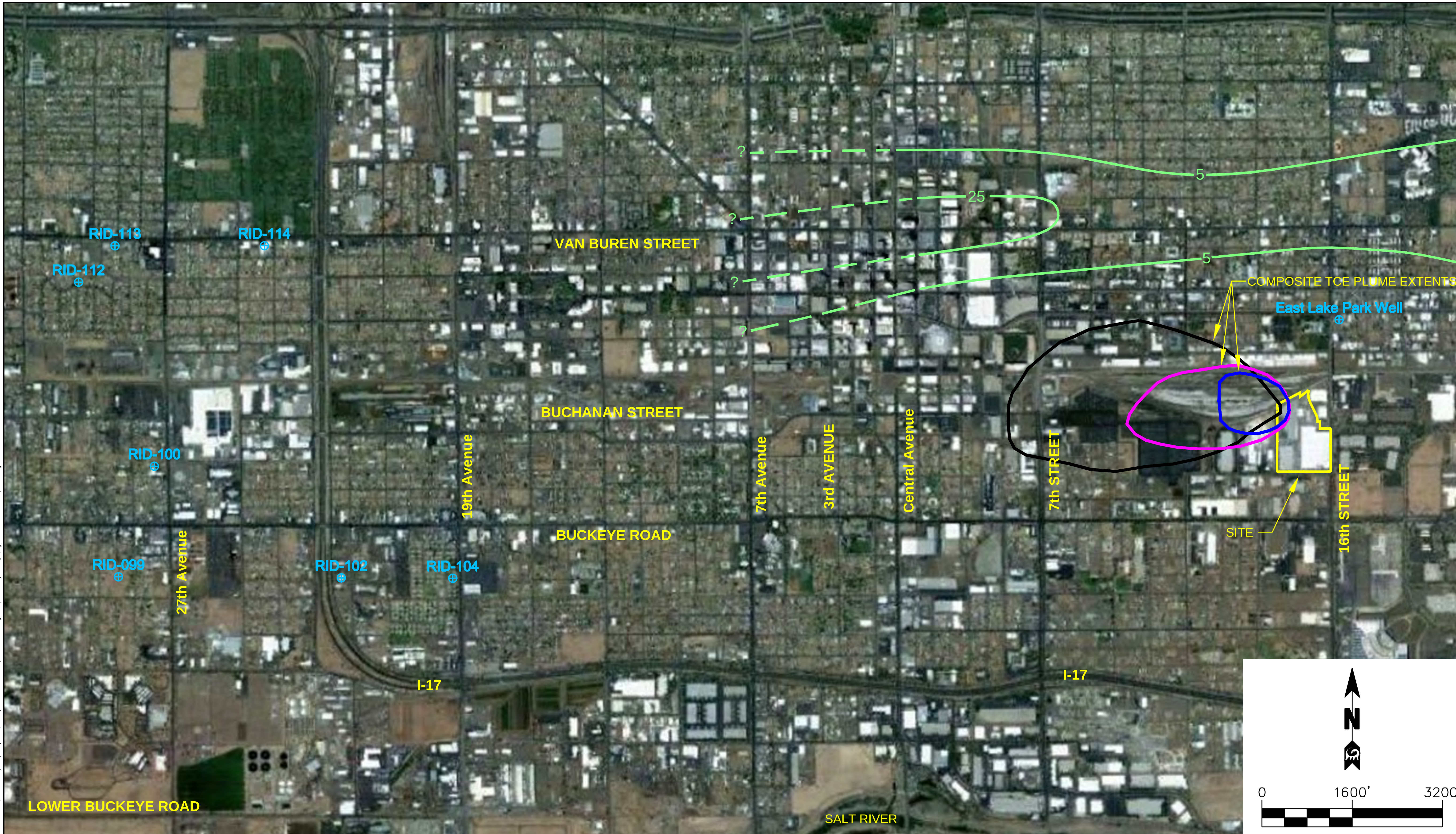
Groundwater Flow and Solute Transport Modeling Report

MODEL-SIMULATED TCE CONCENTRATIONS OVER TIME AT THE PLUME FRONT TARGET (SCENARIO 1e)

500 South 15th Street Facility
Phoenix, Arizona

FIGURE
23



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Groundwater Flow and Solute Transport Modeling Report

LEGEND

5	MARCH 2011 OU3 TCE PLUME CONTOURS (ERM 2012)
	Scenario 1 – BASE CASE
	Scenario 2 – MORE CONSERVATIVE CASE (UNLIKELY)
	Scenario 3 – LESS CONSERVATIVE CASE (UNLIKELY)

MODEL-SIMULATED MAXIMUM COMPOSITE TCE PLUME EXTENT

500 South 15th Street Facility
Phoenix, Arizona

FIGURE

24

Appendix A

Appendix A - Non-Motorola 52^{nd} Street Constituents

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Meritor, Inc.
Cooper Industries, LLC.

Appendix A – Non-Motorola 52nd Street Constituents

500 South 15th Street Facility,
Phoenix, Arizona

January 23, 2013

1.0 Introduction

ARCADIS, on behalf of Meritor, Inc., and Cooper Industries, LLC. (the Amendment Respondents) has prepared this Appendix A to the Groundwater Flow and Solute Transport Modeling Report for the 500 South 15th Street Facility in Phoenix, Arizona. The 500 South 15th Street Facility is located within the Study Area for Operable Unit Three (OU-3) of the Motorola 52nd Street Superfund Site in Phoenix, Arizona. The Motorola 52nd Street Superfund Site was placed on the National Priorities List (NPL) in 1989 and has been identified as a source of groundwater contamination with volatile organic compounds (VOCs); primarily trichloroethene (TCE). The United States Environmental Protection Agency (USEPA) with support from the Arizona Department of Environmental Quality (ADEQ) is overseeing the investigation and remediation activities within the Motorola 52nd Street Superfund Site, including the OU-3 Study Area. USEPA has not yet determined issues of liability in the OU-3 Study Area.

The Respondents are parties to an Administrative Order on Consent (AOC) for Remedial Investigation/Feasibility Study (RI/FS) Docket No. 2004-18 (USEPA, 2004a) with the USEPA dated October 13, 2004, as amended on June 5, 2012 (Amended AOC). This Groundwater Flow and Solute Transport Modeling Report has been prepared to meet the Respondent's requirements under the AOC to evaluate the potential nature and extent of contamination in groundwater beneath the Facility and better understand potential contaminant fate and transport. The nature and extent of contamination in soils and soil vapor beneath the site and the resultant risks to human health and the environment (from soil, soil vapor and groundwater) were addressed in the Final Sitewide Focused Remedial Investigation Report (FRI), dated February 7, 2012 and approved by USEPA on March 29, 2012. It should be noted that the Focused RI was intended to address M52 constituents of concern (M52 COCs). However, non-M52 constituents were also evaluated during work done to investigate the Facility due to the requirements of the AOC. This Appendix A summarizes information regarding non-M52 constituents in soil and groundwater beneath the Facility.

2.0 Summary of Remedial Investigation Results

Historical investigation between 1989 and 2006 at the Facility was completed at potential source areas for contamination. Soil gas investigation, semiannual soil gas sampling and semiannual groundwater sampling have been conducted under the AOC between 2007 to present. Soil gas investigation and semi-annual groundwater sampling for the Focused RI were performed to verify and augment existing data to determine if the Facility is or has been a source of groundwater or soil contamination that has contributed to the known and existing contamination associated with OU-3 Study Area of the Motorola 52nd Street Superfund Site.

Initial soil sampling conducted between 1989 and 2003 has indicated that potential contaminants were present in soils in the Northern Portion of the Facility. Arsenic, and the volatile organic compounds (VOCs), 1,2-dichlorobenzene and 1,4-dichlorobenzene, were reported to exceed the USEPA industrial Regional Screening Levels (i-RSLs). None of the contaminants detected in soils exceed potential leaching criteria to pose a risk to groundwater. Additionally, based on the depth of the contaminants, it is unlikely that these soils would pose a risk to potential human receptors now or into the future. The soil data is summarized on Table A-1.

Soil gas investigation in the Northern Portion of the Facility was conducted near current drywells, and near former solvent and fuel USTs. A total of 82 soil gas samples were collected from 72 soil gas sample locations at depths from nine to 15.2 feet bgs. Analytical results indicated that a number of non-M52 constituents were detected. Of these, 1,2,4-trimethylbenzene, 1,4-dichorobenzene, benzene, chloroform and ethylbenzene exceeded the calculated industrial soil vapor screening level (C-SVSL).

In order to evaluate the vertical extent of COCs reported in the soil gas beneath the AdobeAir Warehouse and address potential for migration of contaminants to groundwater, vapor monitoring well VMW-01 (a four zone nested vapor well) was installed in 2007. A number of non-M52 constituents were detected, but only chloroform exceeded the C-SVSL (Table A-2). Concentrations have not demonstrated any specific trends with depth at vapor monitoring well VMW-01.

Groundwater monitoring wells were installed at the Facility in 1991. Monitoring and sampling was conducted during 1992, then sporadically between 1992 and 2005, and semiannually since 2006 to determine the presence and concentration of COC in groundwater within Facility monitor wells (ARCADIS, 2012). The groundwater monitoring program included monitoring and sampling of six wells (MW-1 through MW-6, located across the entire Facility) between 1992 and 2005, the abandonment of monitor wells MW-1, MW-2, MW-3, MW-5, and MW-6 between 2005 and 2007, and the installation of groundwater monitor wells, MW-7, MW-8 and MW-9 in 2008. Only MW-4 and MW-7 are located in the Northern Portion of the Facility, although Table A-3 includes non-M52 constituents for all on-site wells. Metal constituents have not been analyzed in groundwater samples since 2006.

Table A-1 Summary of Historic Soil Sample Analytical Results Non-M52 Constituents of Concern[a]
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona[a]

Sample Location	Date	Sample Location [1]	Sample Designation	Depth [2] (feet bgs)	pH	Petroleum Hydrocarbons	1,1,2,2-tetrachloroethane	1,2 & 1,4-dichlorobenzene[3]	Bromodichloromethane	Bromoform	Bromomethane	Chloromethane	dichloromethane (Methylene Chloride)	Trichlorofluoromethane	Benzene	Toluene	Ethylbenzene	Xylenes (total)	Benzo(a)anthracene	Benzo(A)pyrene	Benzo(B)Fluoranthene	Benzo(K)Fluoranthene	Chrysene	Fluoranthene	Indeno(1,2,3-CD)pyrene	Pyrene
	ADEQ Residential Soil Remediation Levels (r-SRLs)[4]					NE	0.42	3.5	0.83	69	3.9	48	9.3	390	0.65	650	400	270	0.69	0.069	0.69	6.9	68	2,300	0.69	2,300
	ADEQ Non-residential Soil Remediation Levels (Non-res SRLs)					NE	9.3	79	18	2,200	13	160	210	1,300	1.4	650	400	420	21	2.1	21	210	2,000	22,000	21	29,000
	ADEQ Minimum Groundwater Protection Level (GPL)					NE	NE	NE	NE	NE	NE	NE	NE	NE	0.71	400	120	2,200	NE	NE	NE	NE	NE	NE	NE	NE
	USEPA Regional Screening Levels Residential Soils(r-RSLs)[5]					NE	0.56	2.4	0.27	62	7.3	120	11	790	1.1	5,000	5.4	630	0.15	0.015	0.15	1.5	15	2,300	0.15	1,700
	USEPA Regional Screening Levels Industrial Soils (i-RSLs)					NE	2.8	12	1.4	220	32	500	53	3,400	5.4	45,000	27	2,700	2.1	0.21	2.1	21	210	22,000	2.1	17,000
						USEPA Method 8015 (mg/kg)	USEPA Method 8010/8020 (mg/kg)												USEPA 8310 (mg/kg)							
	11/8/1989	SW of Concrete Tank Structure	R1-1-1A	4	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	SW of Concrete Tank Structure	R1-1-1B	9	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside NE concrete Tank Structure	R1-1-2B	10	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside SW Concrete Tank Structure	R1-1-3A	5	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	East of Gasoline Underground Storage Tanks	R3-1-1B	9	NA	(C16-C24) - 16	NA	NA	NA	NA	NA	NA	NA	NA	<0.025	<0.025	<0.025	<0.025	NA	NA	NA	NA	NA	NA	NA	NA
	12/11/1991	MW-4	MW4-10'	10	NA	NA	<0.010	<0.025	<0.010	<0.01	<0.010	<0.010	<0.100	<0.010	<0.025	<0.025	<0.025	<0.025	NA	NA	NA	NA	NA	NA	NA	NA
	12/13/1991		MW-4-38'[6]	38	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse	SS1	8.3	NA	NA	<0.01	<0.025	<0.01	<0.01	1.1[7]	0.11	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse (~27 feet SW of SS1)	SS2	7.3	NA	NA	<0.01	<0.025	<0.01	<0.01	1.2[7]	0.12	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/1/1994	Outside Northern Boundary of Warehouse (~21 feet SW of SS2)	SS3	8.3	NA	NA	<0.01	<0.025	<0.01	<0.01	0.54[7]	<0.025	<0.1	<0.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/28/1994	Southern Portion of Concrete Structure Excavation Area	EXC-S	5.0	NA	NA	<0.01	<0.025	<0.01	<0.01	<0.025	<0.025	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northern	9/28/1994	Southwest Area of Excavation	EXC-SW	5.0	NA	NA	<0.02	0.35	<0.02	<0.02	<0.050	<0.050	<0.2	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Concrete Structure	UCS-9	10.7	NA	NA	<0.04	<0.100	<0.04	<0.04	<0.100	<0.100	<0.4	<0.100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/11/1994	Inside the Concrete Structure	ICS-BP-21	Inside [8]	NA	NA	<18	<45.0	<18	<18	<45.0	<45.0	<180	<45.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Solution Vessel	USV-11	5.5	NA	NA	<1.0	4.9	5.2	<1.0	<2.50	<2.50	<10	<2.50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/21/1994	Under Solution Vessel	USV-2-24	6.5	NA	NA	<6.0	**90.6**	<1.500	<1.500	<1.500	<1.500	<1.500	<1.500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Pipeline Between Concrete Structure and Sump	UPL-10	9.5	NA	NA	<0.04	<0.100	<0.04	<0.04	<0.100	<0.100	<0.4	<0.100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/21/1994	Under Pipeline Between Concrete Structure and Sump	UPL-2-23	10.4	NA	NA	<0.40	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	East of Sump	EOS-12	2.5	NA	NA	<0.04	<0.100	<0.04	<0.04	<0.100	<0.100	<0.4	<0.100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/26/1994	Under Sump	US-22	6.0	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4/22/2003	Drywell-1	DW-1	15 [2]	NA	(C10-C22) <30 (C22-C32) <100 (C10-C32) <130	<0.05	<0.05	<0.05	<0.005	<0.250	<0.250	<0.250	<0.250	<0.05	<0.05	<0.05	<0.1	<0.02	0.029	0.036	0.022	0.032	0.059	0.053	0.053

Notes:

[a]Soil Samples collected by Scott, Allard & Bohannan (SA&B), unless otherwise noted.

[1] Sample locations shown in Figure 4

[2] Approximate sample depth of sediment collected inside drywells #1 through #4.

[3] Isomers were combined on some lab reports, lowest standard is listed

[4] ADEQ Residential and Non-res SRL Standard A.A.C. R18-7-210 Appendix A adopted May 5, 2007 10[6] risk level or no

[5] USEPA Residential and Industrial RSL Standard November 2011

[6] East Pit sample was analyzed using USEPA method 1311/6010 for TCLP. Arsenic concentration did not fail TCLP criteria

[7] Compound was also found in reagent blank

[8] Soil sampled from inside of concrete structure on 10/11/1994

[9] Chromium III standard was used for Arizona SRLs to be consistent with the USEPA RSL standards.

[10] Cyanide - hydrogen value used for Arizona SRL and USEPA RSL

< = Constituent not detected at or above method reporting limit

mg/kg = milligrams per kilogram

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NA = Not analyzed

NE - Not established

bgs = below ground surface

[D3] Dilution factor of 50 used

Bold = Reported amount exceeds ADEQ Residential and Non-residential SRLs (Non-res SRLs)

Highlight = The area including this sample was excavated and should be excluded from HHRA calculations

Highlight = Reported amount exceeds USEPA Regional Screening Levels Residential Soils

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Sample Location	Date	Sample Location [(1)]	Sample Designation	Depth [(2)] (feet bgs)	Arsenic	Barium	Beryllium	Cadmium	Chromium (Total)[(9)]	Copper	Cyanide[(10)]	Lead	Mercury	Nickel	Selenium	Thallium	Zinc
	ADEQ Residential Soil Remediation Levels (r-SRLs)[(4)]				10	15,000	150	39	120,000	3,100	11	400	23	1,600	390	5.2	23,000
	ADEQ Non-residential Soil Remediation Levels (Non-res SRLs)				10	170,000	1,900	510	1,000,000	41,000	35	800	310	20,000	5,100	67	310,000
	ADEQ Minimum Groundwater Protection Level (GPL)				290	12,000	23	29	590	NE	NE	290	12	590	290	12	NE
	USEPA Regional Screening Levels Residential Soils(r-RSLs)[(5)]				0.39	15,000	160	70	120,000	3,100	47.0	400	23	1,500	390	0.78	23,000
	USEPA Regional Screening Levels Industrial Soils (i-RSLs)				1.6	190,000	2,000	800	1,500,000	41,000	610	800	310	20,000	5,100	10	310,000
Sample Location					Method 6010 (mg/kg)						Method 9012 (mg/kg)	Method 6010 (mg/kg)	Method 7471 (mg/kg)	Method 6010 (mg/kg)			
	11/8/1989	SW of Concrete Tank Structure	R1-1-1A	4	NA	NA	NA	NA	14	NA	NA	<2.5	NA	NA	NA	NA	NA
	11/8/1989	SW of Concrete Tank Structure	R1-1-1B	9	NA	NA	NA	NA	18	NA	NA	<2.5	NA	NA	NA	NA	NA
	11/9/1989	Inside NE concrete Tank Structure	R1-1-2B	10	NA	NA	NA	NA	7	NA	NA	<2.5	NA	NA	NA	NA	NA
	11/8/1989	Inside SW Concrete Tank Structure	R1-1-3A	5	NA	NA	NA	NA	12	NA	NA	<2.5	NA	NA	NA	NA	NA
	11/8/1989	East of Gasoline Underground Storage Tanks	R3-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/11/1991	MW-4	MW4-10'	10	NA	NA	NA	NA	12.5	NA	NA	5	NA	NA	NA	NA	NA
	12/13/1991		MW-4-38'[(6)]	38	NA	NA	NA	NA	21.4	NA	NA	<5	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse	SS1	8.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse (~27 feet SW of SS1)	SS2	7.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/1/1994	Outside Northern Boundary of Warehouse (~21 feet SW of SS2)	SS3	8.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northern	9/28/1994	Southern Portion of Concrete Structure Excavation Area	EXC-S	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/28/1994	Southwest Area of Excavation	EXC-SW	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Concrete Structure	UCS-9	10.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/11/1994	Inside the Concrete Structure	ICS-BP-21	Inside [(8)]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Solution Vessel	USV-11	5.5	11	130	NA	19.8	34.8	NA	**300**	18	<0.1	NA	<5.0	NA	NA
	11/21/1994	Under Solution Vessel	USV-2-24	6.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Pipeline Between Concrete Structure and Sump	UPL-10	9.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/21/1994	Under Pipeline Between Concrete Structure and Sump	UPL-2-23	10.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	East of Sump	EOS-12	2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/26/1994	Under Sump	US-22	6.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4/22/2003	Drywell-1	DW-1	15 [(2)]	3.5	NA	<0.5	0.63	14	200	NA	32	<0.1	8.8	<5.0	<0.1	350

Notes:

[a]Soil Samples collected by Scott, Allard & Bohannan (SA&B), unless otherwise noted.

[(1)] Sample locations shown in Figure 4

[(2)] Approximate sample depth of sediment collected inside drywells #1 through #4.

[(3)] Isomers were combined on some lab reports, lowest standard is listed

[(4)] ADEQ Residential and Non-res SRL Standard A.A.C. R18-7-210 Appendix A adopted May 5, 2007 10^{-6} risk level or no

[(5)] USEPA Residential and Industrial RSL Standard November 2011

[(6)] East Pit sample was analyzed using USEPA method 1311/6010 for TCLP. Arsenic concentration did not fail TCLP criteria

[(7)] Compound was also found in reagent blank

[(8)] Soil sampled from inside of concrete structure on 10/11/1994

[(9)] Chromium III standard was used for Arizona SRLs to be consistent with the USEPA RSL standards.

[(10)] Cyanide - hydrogen value used for Arizona SRL and USEPA RSL

< = Constituent not detected at or above method reporting limit

mg/kg = milligrams per kilogram

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Table A-1 Summary of Historic Soil Sample Analytical Results Non-M52 Constituents of Concern[a]
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona[a]

Sample Location	Date	Sample Location [1]	Sample Designation	Depth [2] (feet bgs)	pH	1,1,2,2-tetrachloroethane	1,2 & 1,4-dichlorobenzene[3]	Bromodichloromethane	Bromoform	Bromomethane	Chloromethane	dichloromethane (Methylene Chloride)	Trichlorofluoromethane	Petroleum Hydrocarbons	Benzene	Toluene	Ethylbenzene	Xylenes (total)	Benzo(a)anthracene	Benzo(A)pyrene	Benzo(B)Fluoranthene	Benzo(K)Fluoranthene	Chrysene	Fluoranthene	Indeno(1,2,3-CD)pyrene	Pyrene
	TCLP Regulatory Levels (mg/L)				NE	NE	7.5	NE	NE	NE	NE	NE	NE	NE	0.5	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
						USEPA Method 8010 & 1311 Toxicity Characteristic Leachate Potential (TCLP) (mg/L)																				
Northern	11/8/1989	SW of Concrete Tank Structure	R1-1-1A	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	SW of Concrete Tank Structure	R1-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside NE concrete Tank Structure	R1-1-2B	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside SW Concrete Tank Structure	R1-1-3A	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	East of Gasoline Underground Storage Tanks	R3-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/6/1989	NE of Drywell R4-1	R4-1-1C	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/6/1989	S of Drywell R4-1	R4-1-2C	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/6/1989	S of Drywell R4-2	R4-2-2C	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/7/1989	S by SE of Drywell R4-3	R4-3-2C	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside SW Concrete Tank Structure	R1-1-3A	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/8/1989	Inside Warehouse	R3-1-1B	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/11/1991	MW-4	MW4-10'	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/13/1991		MW-4-38'[6]	38	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse	SS1	8.3	NA	<0.0002	<0.0005	<0.0002	<0.005	<0.005	<0.0005	0.37[(D3)]	<0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8/31/1994	Outside Northern Boundary of Warehouse (~27 feet SW of SS1)	SS2	7.3	NA	<0.0002	<0.0005	<0.0002	<0.005	<0.005	<0.0005	0.42[(D3)]	<0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/1/1994	Outside Northern Boundary of Warehouse (~21 feet SW of SS2)	SS3	8.3	NA	<0.0002	<0.0005	<0.0002	<0.005	<0.005	<0.0005	0.40 [(D3)]	<0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/28/1994	Southern Portion of Concrete Structure Excavation Area	EXC-S	5.0	NA	<0.002	0.02	<0.002	<0.002	<0.002	<0.002	<0.02	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	9/28/1994	Southwest Area of Excavation	EXC-SW	5.0	NA	<0.002	<0.005	<0.002	<0.002	<0.002		<0.02	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Concrete Structure	UCS-9	10.7	NA	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.02	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/11/1994	Inside the Concrete Structure	ICS-BP-21	Inside [8]	NA	0.011	0.044	<0.01	<0.01	<0.01	<0.01	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Solution Vessel	USV-11	5.5	NA	<0.01	0.036	<0.01	<0.01	<0.01	<0.01	<0.1	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/21/1994	Under Solution Vessel	USV-2-24	6.5	NA	<0.005	0.3	<0.005	<0.005	<0.005	<0.0005	1.1[(D3)]	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	Under Pipeline Between Concrete Structure and Sump	UPL-10	9.5	NA	0.0048	0.026	<0.002	0.016	<0.02	<0.02	<0.02	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/21/1994	Under Pipeline Between Concrete Structure and Sump	UPL-2-23	10.4	NA	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005	1.2[(D3)]	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/7/1994	East of Sump	EOS-12	2.5	NA	<0.004	0.045	<0.004	<0.004	<0.004		<0.04	<0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/26/1994	Under Sump	US-22	6.0	NA	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	1.1[(D3)]	<0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4/22/2003	Drywell-1	DW-1	15 [2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

[a]Soil Samples collected by Scott, Allard & Bohannan (SA&B), unless otherwise noted.

[1] Sample locations shown in Figure 4

[2] Approximate sample depth of sediment collected inside drywells #1 through #4.

[3] Isomers were combined on some lab reports, lowest standard is listed

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Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Other Contaminants (mg/m3)															
Sample Description	Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	1,2,4-Trimethyl-Benzene	1,3,5-Trimethyl-benzene	1,3-Butadiene	1,3-Dichloro-Benzene	1,4-Dichloro-Benzene	2,2,4-Trimethyl-Pentane	2-Butanone (MEK)	2-Hexanone	4-Ethyl-Toluene	4-Methyl-2-pentanone	Acetone	Benzene	Bromo-Dichloro-Methane	Carbon Disulfide	CFC-11	CFC-12
* Calculated Residential Soil Vapor Screening Level						0.73	NE	0.0081	NE	0.022	NE	520	3.1	NE	310	3200	0.031	0.0066	73	73	10
*Calculated Industrial Soil Vapor Screening Level						3.1	NE	0.041	NE	0.11	NE	2200	13	NE	1300	14000	0.16	0.033	310	310	44
Northern Portion	Soil Vapor	AdobeAir Warehouse - Inside (northwest corner) - Phase I Soil Gas Investigation	SG01-(13.3)-092106		13.3	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	0.42 D2
			FD01-092106	SG01-(13.3)-092106	13.3	< .5	< .5	< .22	< .61	< .61	< .47	< .6	< .83	< .44	< .83	< 2.4	< .32	< .68	< .32	< .57	0.55 D2
			SG02-(13.2)-092006		13.2	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG03A-(12.4)-092006		12.4	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG04-(13.0)-092106		13	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	0.39 D2
			SG05A-(14.5)-092106		14.5	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	0.39 D2
			SG06A-(14.5)-092206		14.5	< .012	< .012	< .0056	< .015	< .015	0.035	0.027	< .021	< .011	< .021	0.39 D2	**0.032**	< .017	0.21 D2	< .014	< .013
			SG07-(14.0)-092206		14	< .12	< .12	< .056	< .15	< .15	< .12	< .15	< .21	< .11	< .21	< .6	< .081	< .17	< .079	< .14	< .13
			SG08-(14.5)-092206		14.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG09-(14.5)-092206		14.5	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG10-(13.0)-092006		13	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG11A-(15.0)-092506		15	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG12-(14.7)-09192006P1		14.7	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG12-(14.7)-09192006P3		14.7	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG12-(14.7)-09192006P7		14.7	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG13-(13.2)-092106		13.2	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	0.29 D2
			SG14-(14.4)-092106		14.4	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	0.34 D2
			SG15-(14.8)-092206		14.8	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			FD01-092206	SG15-(14.8)-092206	14.8	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG16-(15.0)-092206		15	< .12	< .12	< .056	< .15	< .15	< .12	< .15	< .21	< .11	< .21	< .6	< .081	< .17	0.11	< .14	< .13
			SG17-(14.7)-092206		14.7	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			FD02-092206	SG17-(14.7)-092206	14.7	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG18-(14.5)-092206		14.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG19-(11.9)-092106		11.9	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG20-(12.4)-092106		12.4	< .12	< .12	< .056	< .15	< .15	< .12	< .15	< .21	< .11	< .21	< .6	< .081	< .17	< .079	< .14	0.26 D2
			SG21-(15.0)-092106		15	< .12	< .12	< .056	< .15	< .15	< .12	< .15	< .21	< .11	< .21	< .6	< .081	< .17	< .079	< .14	0.18
			SG22-(15.2)-092206		15.2	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	0.13	< .057	< .05
			SG23-(14.5)-092206		14.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG24-(14.5)-092206		14.5	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	0.16 D2	< .028	< .025
			SG25-(14.4)-092206		14.4	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
		Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG26-(15.0)-092106		15	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG27-(14.8)-092206		14.8	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG28-(14.2)-092206		14.2	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG29-(14.1)-092206		14.1	< .012	< .012	< .0056	< .015	< .015	< .012	< .015	< .021	< .011	< .021	0.08	< .0081	< .017	0.022	< .014	< .013
			SG30-(14.5)-092506		14.5	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG31-(14.5)-092206		14.5	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	0.024	< .028	< .025
			SG32-(14.0)-092206		14	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	0.027	< .028	< .025
			SG33-(13.0)-092506		13	< .012	< .012	< .0056	< .015	< .015	< .012	< .015	< .021	< .011	< .021	0.19 D2	< .0081	< .017	0.016	< .014	< .013
			SG34-(14.1)-092506		14.1	< .005	< .005	< .0022	< .0061	0.0067	0.011	0.022	< .0083	< .0044	< .0083	0.11	0.011	< .0068	0.019	0.0068	< .005
	AdobeAir Warehouse - Inside (northwest corner) - Phase II Soil Gas Investigation		SG65-(11)-12102007		11	**1.1 D2**	0.4 D2	< .011	< .031	< .031	< .024	< .03	< .042	0.28 D2	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG66-(12)-12102007		12	< .15	< .044	< .011	< .031	< .031	< .024	< .03	< .042	< .062	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG67-(11)-12102007		11	**1.2 D2**	0.32 D2	< .011	< .031	< .033	< .024	< .03	< .042	< .19	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG68-(11)-12102007		11	< .055	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			DUP01-(11)-12102007	SG68-(11)-12102007	11	< .055	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .038	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG70-(12)-12102007		12	< .048	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .038	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG71-(12)-12102007		12	< .047	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .039	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG72-(10)-12102007		10	< .05	< .027	< .011	< .031	< .031	< .024	< .03	< .042	< .043	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG73-(10.5)-12112007		10.5	< .055	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .041	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG74-(10)-12112007		10	< .11	< .033	< .011	< .031	< .031	< .024	< .03	< .042	< .053	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG75-(12)-12112007		12	< .044	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
			SG76-(10)-12112007		10	< .085	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG77-(11)-12112007		11	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG78-(10.5)-12112007		10.5	< .085	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			DUP01-(10.5)-12112007	SG78-(10.5)-12112007	10.5	< .085	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG79-(12.5)-12052007		12.5	**3.9 D2**	1.8 D2	< .022	< .061	< .061	0.12	0.13	< .083	1.2 D2	< .083	0.82 D2	**0.11**	< .068	< .032	< .057	< .05
			SG80-(9.5)-12112007		9.5	< .085	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG81-(11)-12112007		11	< .08	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG82-(10)-12112007		10	< .08	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG83-(10)-12052007		10	**0.75 D2**	0.29 D2	< .022	< .061	< .061	0.37 D2	< .06	< .083	0.26 D2	< .083	< .24	**0.11**	< .068	< .032	< .057	< .05
			SG84-(10)-12112007		10	< .08	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG85-(10)-12112007		10	< .09	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG86-(10)-12112007		10	< .09	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
			SG87-(12)-12052007		12	**2.5 D2**	0.9 D2	< .022	< .061	< .061	0.076	< .06	< .083	0.57 D2	< .083	< .24	**0.032**	< .068	< .032	< .057	< .05

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Other Contaminants (mg/m3)															
Sample Description	Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	Chloroform	Chloro-Methane	Cyclohexane	Dichloro-Methane	Ethyl Acetate	Ethylbenzene	Heptane	Hexane	m,p-Xylene	Methyl tert-butyl ether	o-Xylene	Propene	Styrene (Monomer)	Tetra-Hydrofuran	Toluene	Vinyl Acetate
* Calculated Residential Soil Vapor Screening Level						0.011	9.4	630	0.52	NE	0.097	NE	73	10 [1]	0.94	10 [1]	310	100	NE	520	21
*Calculated Industrial Soil Vapor Screening Level						0.053	39	2600	2.6	NE	0.49	NE	310	44 [1]	4.7	44 [1]	1300	440	NE	2200	88
Northern Portion	Soil Vapor	AdobeAir Warehouse - Inside (northwest corner) - Phase I Soil Gas Investigation	SG01-(13.3)-092106		13.3	< .25	< .1	< .17	0.18 D2	0.19 D2	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	< .19	< .18
			FD01-092106	SG01-(13.3)-092106	13.3	< .5	< .21	< .35	< .35	< .37	< .44	< .42	< .36	< .88	< .73	< .44	< .18	< .43	< 1.2	< .38	< .36
			SG02-(13.2)-092006		13.2	**0.074**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG03A-(12.4)-092006		12.4	**0.064**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.044	< .043	< .12	0.08	< .036
			SG04-(13.0)-092106		13	< .25	< .1	< .17	0.18 D2	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	0.21 D2	< .18
			SG05A-(14.5)-092106		14.5	< .25	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	0.23 D2	< .18
			SG06A-(14.5)-092206		14.5	< .012	< .0052	0.028	< .0088	0.013	< .011	0.05	0.046	< .022	< .018	< .011	< .0044	< .011	< .03	1 D2	< .0089
			SG07-(14.0)-092206		14	< .12	< .052	< .087	< .088	< .092	< .11	< .1	< .089	< .22	< .18	< .11	< .044	< .11	< .3	0.14	< .089
			SG08-(14.5)-092206		14.5	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG09-(14.5)-092206		14.5	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	0.026	< .022	< .06	< .019	< .018
			SG10-(13.0)-092006		13	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.063	< .043	< .12	< .038	< .036
			SG11A-(15.0)-092506		15	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	< .019	< .018
			SG12-(14.7)-09192006P1		14.7	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.051	< .043	< .12	0.061 U	< .036
			SG12-(14.7)-09192006P3		14.7	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.051	< .043	< .12	0.061 U	< .036
			SG12-(14.7)-09192006P7		14.7	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.052	< .043	< .12	0.069 U	< .036
			SG13-(13.2)-092106		13.2	< .25	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	0.25 D2	< .18
			SG14-(14.4)-092106		14.4	< .25	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	0.42 D2	< .18
			SG15-(14.8)-092206		14.8	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			FD01-092206	SG15-(14.8)-092206	14.8	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG16-(15.0)-092206		15	< .12	< .052	< .087	< .088	< .092	< .11	< .1	< .089	< .22	< .18	< .11	0.33 D2	< .11	< .3	0.1	< .089
			SG17-(14.7)-092206		14.7	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.037	< .043	< .12	0.046	< .036
			FD02-092206	SG17-(14.7)-092206	14.7	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.033	< .043	< .12	0.038	< .036
			SG18-(14.5)-092206		14.5	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.042	< .043	< .12	< .038	< .036
			SG19-(11.9)-092106		11.9	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG20-(12.4)-092106		12.4	< .12	< .052	< .087	0.11	0.11	< .11	< .1	< .089	< .22	< .18	< .11	< .044	< .11	< .3	0.13	< .089
			SG21-(15.0)-092106		15	< .12	< .052	< .087	< .088	< .092	< .11	< .1	< .089	< .22	< .18	< .11	< .044	< .11	< .3	0.21 D2	< .089
			SG22-(15.2)-092206		15.2	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG23-(14.5)-092206		14.5	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.061	< .043	< .12	19 D2	< .036
			SG24-(14.5)-092206		14.5	< .025	< .01	< .017	< .018	0.092	< .022	< .021	< .018	< .044	< .037	< .022	0.063	< .022	< .06	0.065	< .018
			SG25-(14.4)-092206		14.4	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.033	< .043	< .12	< .038	< .036
		Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG26-(15.0)-092106		15	**0.059**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.056	< .043	< .12	0.046	< .036
			SG27-(14.8)-092206		14.8	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	0.11	< .036
			SG28-(14.2)-092206		14.2	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.04	< .043	< .12	0.077	< .036
			SG29-(14.1)-092206		14.1	< .012	< .0052	< .0087	< .0088	< .0092	< .011	< .01	< .0089	< .022	< .018	< .011	0.077	< .011	< .03	0.021	< .0089
			SG30-(14.5)-092506		14.5	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	0.049	< .022	< .06	< .019	< .018
			SG31-(14.5)-092206		14.5	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	0.044	< .022	< .06	0.031	< .018
			SG32-(14.0)-092206		14	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	0.08	< .022	< .06	0.026	< .018
			SG33-(13.0)-092506		13	**0.027**	< .0052	< .0087	< .0088	< .0092	< .011	0.017	0.022	< .022	< .018	< .011	0.24 D2	< .011	< .03	0.014	< .0089
			SG34-(14.1)-092506		14.1	**0.05**	< .0021	< .0035	< .0035	0.014	< .0044	0.012	0.02	< .0088	< .0073	< .0044	0.068	< .0043	< .012	< .0038	< .0036
		AdobeAir Warehouse - Inside (northwest corner) - Phase II Soil Gas Investigation	SG65-(11)-12102007		11	< .025	< .01	< .017	< .018	< .018	**0.17**	0.03	< .018	0.84 D2	< .037	0.23 D2	< .0088	< .022	< .06	0.22 D2	< .018
			SG66-(12)-12102007		12	< .025	< .01	< .017	< .018	< .018	0.038	< .021	< .018	0.11	< .037	0.026	< .0088	< .022	< .06	0.028	< .018
			SG67-(11)-12102007		11	< .025	< .01	< .017	< .018	< .018	0.079	0.023	< .018	0.38 D2	< .037	0.12	< .0088	< .022	< .06	0.08	< .018
			SG68-(11)-12102007		11	< .025	< .01	< .017	< .018	< .018	0.027	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	< .019	< .018
			DUP01-(11)-12102007	SG68-(11)-12102007	11	< .025	< .01	< .017	< .018	< .018	0.028	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	< .019	< .018
			SG70-(12)-12102007		12	< .025	< .01	< .017	< .018	< .018	< .022	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	< .019	< .018
			SG71-(12)-12102007		12	< .025	< .01	< .017	< .018	< .018	0.03	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	0.021	< .018
			SG72-(10)-12102007		10	< .025	< .01	< .017	< .018	< .018	0.028	< .021	< .018	0.066	< .037	0.023	< .0088	< .022	< .06	0.034	< .018
			SG73-(10.5)-12112007		10.5	< .025	< .01	< .017	< .018	< .018	0.033	< .021	< .018	0.07	< .037	< .022	< .0088	< .022	< .06	0.028	< .018
			SG74-(10)-12112007		10	**0.047**	< .01	< .017	< .018	< .018	0.044	< .021	< .018	0.15	< .037	0.029	< .0088	< .022	< .06	0.057	< .018
			SG75-(12)-12112007		12	**0.042**	< .01	< .017	< .018	< .018	0.03	< .021	< .018	< .044	< .037	< .022	< .0088	< .022	< .06	0.02	< .018
			SG76-(10)-12112007		10	**0.064**	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG77-(11)-12112007		11	**0.064**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG78-(10.5)-12112007		10.5	**0.079**	< .021	< .035	< .035	< .037	0.07	< .042	< .036	0.15	< .073	< .044	< .018	< .043	< .12	0.2 D2	< .036
			DUP01-(10.5)-12112007	SG78-(10.5)-12112007	10.5	**0.064**	< .021	< .035	< .035	< .037	0.066	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	0.12	< .036
			SG79-(12.5)-12052007		12.5	< .05	< .021	< .035	< .035	0.27 D2	**0.79 D2**	0.35 D2	< .036	3.5 D2	< .073	1.1 D2	0.028	< .043	< .12	1.5 D2	< .036
			SG80-(9.5)-12112007		9.5	**0.089**	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG81-(11)-12112007		11	**0.16**	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG82-(10)-12112007		10	**0.064**	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG83-(10)-12052007		10	< .05	< .021	< .035	< .035	< .037	**0.48 D2**	0.71 D2	< .036	1.8 D2	< .073	0.4 D2	0.021	< .043	< .12	1.4 D2	< .036
			SG84-(10)-12112007		10	**0.1**	< .021	< .035	< .035	< .037	0.062	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	0.11	< .036
			SG85-(10)-12112007		10	**0.054**	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
			SG86-(10)-12112007		10	**0.05**	< .021	< .035	< .035	< .037	0.062	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	0.054	< .036
			SG87-(12)-12052007		12	< .05	< .021	< .035	< .035	0.051	**0.75 D2**	0.3 D2	< .036	3 D2	< .073	0.84 D2	0.051	< .043	< .12	1.1 D2	< .036

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information							Other Contaminants (mg/m3)																		
Sample Description		Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	1,2,4-Trimethyl-Benzene	1,3,5-Trimethyl-benzene	1,3-Butadiene	1,3-Dichloro-Benzene	1,4-Dichloro-Benzene	2,2,4-Trimethyl-Pentane	2-Butanone (MEK)	2-Hexanone	4-Ethyl-Toluene	4-Methyl-2-pentanone	Acetone	Benzene	Bromo-Dichloro-Methane	Carbon Disulfide	CFC-11	CFC-12
* Calculated Residential Soil Vapor Screening Level							0.73	NE	0.0081	NE	0.022	NE	520	3.1	NE	310	3200	0.031	0.0066	73	73	10
*Calculated Industrial Soil Vapor Screening Level							3.1	NE	0.041	NE	0.11	NE	2200	13	NE	1300	14000	0.16	0.033	310	310	44
Northern Portion	Soil Vapor	AdobeAir Warehouse - Outside (Northwest) - Phase II & III Soil Gas Investigation	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG90-(15)-12042007		15	< .025	< .025	< .011	< .031	< .031	< .024	< .03	< .042	< .022	< .042	< .12	< .016	< .034	< .016	< .028	< .025
				DUP01-(15)-12042007	SG90-(15)-12042007	15	< .08	0.03	< .011	< .031	**0.034**	< .024	< .03	< .042	0.062	< .042	0.12	< .016	< .034	< .016	< .028	< .025
				SG91-(15)-12112007		15	< .02	< .012	< .0056	< .015	< .015	< .012	< .015	< .021	< .011	< .021	< .06	< .0081	< .017	< .0079	< .014	< .013
				SG92-(15)-12112007		15	< .1	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .075	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				SG-97-14.5-090908		14.5	< .0482	< .0482	< .0216	< .0589	< .0589	< .0458	< .059	< .0819	< .0482	< .0819	< .233	< .0313	< .0657	< .0305	< .0551	< .0485
				SG-98-12-090908		12	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				DUP-090908	SG-98-12-090908	12	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				SG-99-11-090908		11	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				SG-100-10-090908		10	< .00492	< .00492	< .00221	< .00601	0.016	< .00467	0.22	0.013	< .00492	< .00819	0.38	0.024	< .0067	0.0047	0.0056	< .00495
		AdobeAir Warehouse-Outside (Northeast)		SG-101-15-090908		15	< .0477	< .0477	< .0214	< .0583	**0.096**	< .0453	< .056	< .0778	< .0477	< .0778	< .23	< .031	< .065	< .0302	< .0545	< .048
				SG-102-15-090908		15	< .0123	< .0123	< .00552	< .015	**0.17**	< .0117	< .0147	< .0205	< .0123	< .0205	< .0594	0.011	< .0168	< .00778	< .014	< .0124
		AdobeAir Warehouse - Outside (west)	Dry Well (R4-5)	SG50-(10.0)-092506		10	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				SG93-(10)-12112007		10	< .022	< .012	< .0056	< .015	< .015	< .012	< .015	< .021	< .011	< .021	< .06	< .0081	< .017	< .0079	< .014	< .013
				SG94-(15)-12052007		15	< .055	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				SG-95-10-090908		10	< .0487	< .0487	< .0219	< .0595	**0.1**	< .0463	< .059	< .0819	< .0487	< .0819	< .235	< .0316	< .0663	< .0308	< .0556	< .049
				SG-96-10-090908		10	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
		AdobeAir Warehouse - Inside (west)		SG88-(12.5)-12052007		12.5	**0.85 D2**	0.32 D2	< .011	< .031	< .031	0.71 D2	< .03	< .042	0.26 D2	< .042	< .12	**0.24 D2**	< .034	< .016	< .028	< .025
				SG89-(15)-12052007		15	0.7	0.27	< .0056	< .015	< .015	0.15	< .015	< .021	0.23	< .021	< .06	**0.052**	< .017	< .0079	0.017	< .013
		AdobeAir Warehouse - Inside (northwest corner) - Semi Annual Vapor Sampling from Vapor Monitoring Well VMW-01	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	VW-01(12.5)-01212008		12.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(12.5)-1-03172008		12.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(12.5)-3-03172008		12.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(12.5)-7-03172008		12.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(12.5)091008 [2]		12.5	< .123	< .123	< .0552	< .15	< .15	< .117	< .147	< .205	< .123	< .205	< .594	< .0799	< .168	< .0778	< .14	< .124
				VMW01(12.5)03192009		12.5	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW-01(12.5)-091009		12.5	< .123	< .123	< .0552	< .15	< .15	< .117	< .147	< .205	< .123	< .205	< .594	< .0799	< .168	< .0778	< .14	< .124
				VMW-01-(12.5)-03172010		12.5	0.0033 UB	0.0011 J	< .0011	< .00301	0.0017 J	< .00234	0.00089 J	0.0012 J	0.001 J	< .0041	0.011 J	0.0029	< .00335	0.0028	0.0047	0.0025
				VMW-01(12.5)-09092010		12.5	0.0029	< .0025	< .0011	< .003	< .003	< .00234	< .00295	< .0041	< .0025	< .0041	0.013 UB	0.0035	< .0034	0.0027	0.0046	< .0025
		AdobeAir Warehouse - Inside (northwest corner) - Semi Annual Vapor Sampling from Vapor Monitoring Well VMW-01		VW-01(40)-01212008		40	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(40)-033108		40	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	< .25
				VMW-01(45)091008 [2]		40	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW01(40)03192009		40	0.25	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW-01(40)-091009		40	< .0487	< .0487	< .0219	< .0595	< .0595	< .0463	< .059	< .0819	< .0487	< .0819	< .235	< .0316	< .0663	< .0308	< .0556	< .049
				VMW-01-(40)-03172010		40	0.0054	0.002 J	< .0011	< .00301	0.0028 J	0.002 J	0.019	0.002 J	< .00246	0.0016 J	0.11	0.012	0.0012 J	0.011	0.0036	0.0024 J
				VMW-01(40)-09092010		40	< 0.0379 U	< .038	< .017	< .046	< .046	< .036	< .0442	< .061	< .038	< .061	< .183	< .025	< .052	< .024	< .043	< .038
				VW-01(55)-01212008		55	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	< .032	< .057	< .05
				VMW-01(55)-033108		55	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	< .25
				VMW-01(55)091008 [2]		55	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW01(55)03192009		55	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				DUP-03192009	VMW01(55)03192009	55	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	1.3	< .16	< .335	0.26	< .281	< .247
				VMW-01(55)-091009		55	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .29 UB	< .335	< .156	< .281	< .247
				VMW-01-(55)-03172010		55	< .0093	< .00246	< .0011	< .00301	0.0022 J	< .00234	< .00295	0.0018 J	< .00246	< .0041	0.0081 J	0.0093	0.0017 J	0.0047	0.0036	0.0024 J
				VMW-01(55)-09092010		55	< .037	< .037	< .017	< .045	< .045	< .035	< .044	< .061	< .037	< .061	< .18	< .024	< .05	< .0234	< .0421	< .037
				DUP-09092010	VMW-01(55)-09092010	55	< .036	< .036	< .016	< .045	< .045	< .035	< .044	< .061	< .036	< .061	< .18	< .0236	< .05	< .023	< .0416	< .037
				VW-01(79.5)-01212008		79.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	0.073	< .057	< .05
				DUP-01212008	VW-01(79.5)-01212008	79.5	< .05	< .05	< .022	< .061	< .061	< .047	< .06	< .083	< .044	< .083	< .24	< .032	< .068	0.082	< .057	< .05
				VMW-01(79.5)-033108		79.5	< .25	< .25	< .11	< .31	< .31	< .24	< .3	< .42	< .22	< .42	< 1.2	< .16	< .34	< .16	< .28	< .25
				VMW-01(79.5)091008 [2]		79.5	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				DUP-091008 [2]	VMW-01(79.5)091008	79.5	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW01(79.5)03192009		79.5	0.43	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	0.25	< .281	< .247
				VMW-01(79.5)-091009		79.5	< .27	< .27	< .121	< .331	< .331	< .257	< .324	< .451	< .27	< .451	< 1.31	< .176	< .369	< .171	< .309	< .272
				DUP-091009	VMW-01(79.5)-091009	79.5	< .246	< .246	< .11	< .301	< .301	< .234	< .295	< .41	< .246	< .41	< 1.19	< .16	< .335	< .156	< .281	< .247
				VMW-01-(79.5)-03172010		79.5	0.031	0.019 J	< .0011	< .00301	0.0023 J	0.00084 J	< .00295	0.0014 J	0.0089 J	< .0041	0.0071 J	0.02 J	< .00335	0.0034	0.0042	< .00247
				DUP-03172010	VMW-01-(79.5)-03172010	79.5	< .00246 UJ	< .00246 UJ	< .0011	< .00301	0.0016 J	< .00234	< .00295	0.00061 J	< .00246 UJ	< .0041	< .0119	0.0038 J	< .00335	0.0034	0.0042	< .00247
		AdobeAir Warehouse - Inside (NW Corner) Soil Vapor Extraction Pilot Test at VMW-01		SVE1VMW-01 (12.5) 091108		12.5	< .0487	< .0487	< .0219	< .0595	< .0595	< .0463	< .059	< .0819	< .0487	< .0819	< .235	< .0316	< .0663	< .0308	< .0556	< .049
				SVE2VMW-01 (12.5) 091108		12.5	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				SVE1VMW-01 (40) 091108		40	< .00492	< .00492	< .00221	< .00601	< .00601	< .00467	< .0059	< .00819	< .00492	< .00819	0.14	< .00319	< .0067	< .00311	< .00562	< .00495
				SVE2VMW-01 (40) 091108		40	< .0482	< .0482	< .0216	< .0589	< .0589	< .0458	< .059	< .0819	< .0482	< .0819	< .233	< .0313	< .0657	< .0305	< .0551	< .0485
				SVE-CVMW-01(40)091208		40	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				SVE-CVMW-01(55)091208		55	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information							Other Contaminants (mg/m3)															
Sample Description		Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	Chloroform	Chloro-Methane	Cyclohexane	Dichloro-Methane	Ethyl Acetate	Ethylbenzene	Heptane	Hexane	m,p-Xylene	Methyl tert-butyl ether	o-Xylene	Propene	Styrene (Monomer)	Tetra-Hydrofuran	Toluene	Vinyl Acetate
* Calculated Residential Soil Vapor Screening Level							0.011	9.4	630	0.52	NE	0.097	NE	73	10 [1]	0.94	10 [1]	310	100	NE	520	21
*Calculated Industrial Soil Vapor Screening Level							0.053	39	2600	2.6	NE	0.49	NE	310	44 [1]	4.7	44 [1]	1300	440	NE	2200	88
Northern Portion	Soil Vapor	AdobeAir Warehouse - Outside (Northwest) - Phase II & III Soil Gas Investigation	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	SG90-(15)-12042007		15	< .025	< .01	< .017	< .018	< .018	0.022	< .021	< .018	0.044	< .037	< .022	0.093 D2	< .022	< .06	0.036	< .018
				DUP01-(15)-12042007	SG90-(15)-12042007	15	< .025	< .01	< .017	< .018	< .018	0.048	0.024	< .018	0.13	< .037	0.031	0.15 D2	< .022	< .06	0.057	< .018
				SG91-(15)-12112007		15	< .012	< .0052	< .0087	< .0088	< .0092	0.013	< .01	< .0089	< .022	< .018	< .011	< .0044	< .011	< .03	< .0096	< .0089
				SG92-(15)-12112007		15	< .05	< .021	< .035	< .035	< .037	0.057	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
				SG-97-14.5-090908		14.5	< .0478	< .0202	< .0337	< .034	< .0353	< .0426	< .0402	< .0345	< .0868	< .0721	< .0426	< .0169	< .0417	< .115	< .0369	< .0345
				SG-98-12-090908		12	< .0488	< .0206	0.29	< .0347	< .036	< .0434	0.14	0.46	< .0868	< .0721	< .0434	< .0172	< .0426	< .118	< .0377	< .0352
				DUP-090908	SG-98-12-090908	12	< .0488	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .118	< .0377	< .0352
				SG-99-11-090908		11	< .0488	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .121	< .0377	< .0352
				SG-100-10-090908		10	0.0078	< .00206	< .00344	< .00347	< .0036	< .00434	< .0041	< .0352	< .00868	< .00721	< .00434	0.031	< .00426	0.026	0.0053	< .00352
		AdobeAir Warehouse-Outside (Northeast)		SG-101-15-090908		15	< .0474	< .02	< .0334	< .0337	< .035	< .0421	< .0398	< .0342	< .0825	< .0685	< .0421	< .0167	< .0413	< .115	< .0366	< .0342
				SG-102-15-090908		15	< .0122	< .00516	< .00861	< .00868	< .00901	< .0109	< .0102	< .0088	< .0217	< .018	< .0109	0.0045	< .0106	< .0295	< .00942	< .0088
		AdobeAir Warehouse - Outside (west)	Dry Well (R4-5)	SG50-(10.0)-092506		10	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
				SG93-(10)-12112007		10	< .012	< .0052	< .0087	< .0088	< .0092	0.013	< .01	< .0089	< .022	< .018	< .011	< .0044	< .011	< .03	< .0096	< .0089
				SG94-(15)-12052007		15	< .05	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.018	< .043	< .12	< .038	< .036
				SG-95-10-090908		10	< .0483	< .0204	< .0341	< .0344	< .0357	< .043	< .0406	< .0349	< .0868	< .0721	< .043	< .017	< .0422	< .118	< .0373	< .0349
				SG-96-10-090908		10	**0.078**	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .121	< .0377	< .0352
		AdobeAir Warehouse - Inside (west)		SG88-(12.5)-12052007		12.5	**0.054**	< .01	< .017	< .018	< .018	**0.44 D2**	1.5 D2	0.057	1.8 D2	< .037	0.4 D2	0.028	< .022	< .06	1.9 D2	< .018
				SG89-(15)-12052007		15	**0.025**	< .0052	< .0087	< .0088	< .0092	**0.4**	0.35	0.021	1.6	< .018	0.4	0.056	< .011	< .03	0.84	< .0089
		AdobeAir Warehouse - Inside (northwest corner) - Semi Annual Vapor Sampling from Vapor Monitoring Well VMW-01	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	VW-01(12.5)-01212008		12.5	**0.099**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.21 D2	< .043	< .12	< .038	< .036
				VMW-01(12.5)-1-03172008		12.5	**0.074**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
				VMW-01(12.5)-3-03172008		12.5	**0.05**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
				VMW-01(12.5)-7-03172008		12.5	**0.084**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	< .018	< .043	< .12	< .038	< .036
				VMW-01(12.5)091008 [2]		12.5	**0.14**	< .0516	< .0861	< .0868	< .0901	< .109	< .102	< .0881	< .217	< .18	< .109	< .043	< .106	< .295	< .0942	< .088
				VMW01(12.5)03192009		12.5	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW-01(12.5)-091009		12.5	< .122	< .0516	< .0861	< .0868	< .0901	< .109	< .102	< .0881	< .217	< .18	< .109	< .043	< .106	< .295	< .0942	< .088
				VMW-01-(12.5)-03172010		12.5	**0.078**	0.00039 J	0.0001 J	0.0042	< .0018	0.00096 J	< .00205	0.00085 J	0.0056	< .00361	0.0017 J	< .000861	< .00213	< .0059	0.0045	< .00176
				VMW-01(12.5)-09092010		12.5	**0.064**	< .001	< .0017	0.0069	< .0018	< .0022	< .0021	< .0018	< .0043	< .0036	< .0022	< .00086	0.006	< .0059	0.0049 UB	< .0018
		AdobeAir Warehouse - Inside (northwest corner) - Semi Annual Vapor Sampling from Vapor Monitoring Well VMW-01		VW-01(40)-01212008		40	**0.11**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.15 D2	< .043	< .12	< .038	< .036
				VMW-01(40)-033108		40	**0.31 D2**	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	< .19	< .18
				VMW-01(45)091008 [2]		40	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW01(40)03192009		40	**0.28**	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW-01(40)-091009		40	< .0483	< .0204	< .0341	< .0344	< .0357	< .043	< .0406	< .0349	< .0868	< .0721	< .043	< .017	< .0422	< .115	< .0373	< .0349
				VMW-01-(40)-03172010		40	**0.11**	< .00103	0.0022	0.0083	< .0018	0.0042	< .00205	0.003	0.017	< .00361	0.0091	< .000861	0.0013 J	< .0059	0.038	0.00053 J
				VMW-01(40)-09092010		40	**0.093**	< .016	< .027	< .027	< .028	< .033	< .032	< .027	< .065	< .054	< .033	< .013	< .033	< .091	< .029	< .027
				VW-01(55)-01212008		55	**0.074**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.018	< .043	< .12	< .038	< .036
				VMW-01(55)-033108		55	**0.33**	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	< .19	< .18
				VMW-01(55)091008 [2]		55	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW01(55)03192009		55	**0.28**	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				DUP-03192009	VMW01(55)03192009	55	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW-01(55)-091009		55	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	0.65	< .361 U	< .217	< .0861	< .213	< .59	< .94 UB	< .176
				VMW-01-(55)-03172010		55	**0.21**	< .00103	0.001 J	0.017	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	0.002	< .00176
				VMW-01(55)-09092010		55	**0.15**	< .016	< .026	< .0261	< .027	< .033	< .031	< .026	< .065	< .054	< .033	< .013	< .0319	< .089	< .0283	< .026
				DUP-09092010	VMW-01(55)-09092010	55	**0.12**	< .015	< .026	< .0257	< .027	< .032	< .03	< .026	< .065	< .054	< .032	< .013	< .0315	< .089	< .0279	< .026
				VW-01(79.5)-01212008		79.5	**0.18**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.037	< .043	< .12	< .038	< .036
				DUP-01212008	VW-01(79.5)-01212008	79.5	**0.21**	< .021	< .035	< .035	< .037	< .044	< .042	< .036	< .088	< .073	< .044	0.042	< .043	< .12	< .038	< .036
				VMW-01(79.5)-033108		79.5	**0.48**	< .1	< .17	< .18	< .18	< .22	< .21	< .18	< .44	< .37	< .22	< .088	< .22	< .6	< .19	< .18
				VMW-01(79.5)091008 [2]		79.5	**0.29**	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				DUP-091008 [2]	VMW-01(79.5)091008	79.5	**0.26**	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW01(79.5)03192009		79.5	**0.93**	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW-01(79.5)-091009		79.5	< .269	< .114	< .189	< .191	< .198	< .239	< .225	< .194	< .478	< .397	< .239	< .0947	< .234	< .649	< .207	< .194
				DUP-091009	VMW-01(79.5)-091009	79.5	< .244	< .103	< .172	< .174	< .18	< .217	< .205	< .176	< .434	< .361	< .217	< .0861	< .213	< .59	< .188	< .176
				VMW-01-(79.5)-03172010		79.5	**0.14**	0.00056 J	< .00172	0.0052	< .0018	0.017 J	0.0018 J	0.0017 J	0.078 J	< .00361	0.028 J	< .000861	< .00213	< .0059	0.094 J	< .00176
				DUP-03172010	VMW-01-(79.5)-03172010	79.5	**0.14**	0.00047 J	< .00172	0.0056	< .0018	< .00217 UJ	< .00205	0.0071 J	0.0014 J	0.0021 J	< .00217	NA	< .00213	< .0059	0.0029 J	< .00176
		AdobeAir Warehouse - Inside (NW Corner) Soil Vapor Extraction Pilot Test at VMW-01		SVE1VMW-01 (12.5) 091108		12.5	**0.12**	< .0204	< .0341	< .0344	< .0357	< .043	< .0406	< .0349	< .0868	< .0721	< .043	< .017	< .0422	< .115	< .0373	< .0349
				SVE2VMW-01 (12.5) 091108		12.5	**0.064**	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .121	< .0377	< .0352
				SVE1VMW-01 (40) 091108		40	< .00488	< .00206	< .00344	< .00347	< .0036	< .00434	< .0041	< .00352	< .00868	< .00721	< .00434	< .00172	< .00426	< .0118	< .00377	< .00352
				SVE2VMW-01 (40) 091108		40	**0.12**	< .0202	< .0337	< .034	< .0353	< .0426	< .0402	< .0345	< .0868	< .0721	< .0426	< .0169	< .0417	< .115	< .0369	< .0345
				SVE-CVMW-01(40)091208		40	**0.13**	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .118	< .0377	< .0352
				SVE-CVMW-01(55)091208		55	**0.16**	< .0206	< .0344	< .0347	< .036	0.043	< .041	< .0352	0.42	< .0721	0.091	< .0172	< .0426	< .118	0.09	< .0352

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information							Other Contaminants (mg/m3)															
Sample Description		Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	1,2,4-Trimethyl-Benzene	1,3,5-Trimethyl-benzene	1,3-Butadiene	1,3-Dichloro-Benzene	1,4-Dichloro-Benzene	2,2,4-Trimethyl-Pentane	2-Butanone (MEK)	2-Hexanone	4-Ethyl-Toluene	4-Methyl-2-pentanone	Acetone	Benzene	Bromo-Dichloro-Methane	Carbon Disulfide	CFC-11	CFC-12
* Calculated Residential Soil Vapor Screening Level							0.73	NE	0.0081	NE	0.022	NE	520	3.1	NE	310	3200	0.031	0.0066	73	73	10
*Calculated Industrial Soil Vapor Screening Level							3.1	NE	0.041	NE	0.11	NE	2200	13	NE	1300	14000	0.16	0.033	310	310	44
Northern Portion	Soil Vapor	AdobeAir Warehouse - Outside (Northwest) - SVE Pilot Test Baseline, Vapor Monitoring Well Samples	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	VMW-02(10)-091108[2]		10	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				VMW-02(40)091008[2]		40	0.11	< .0487	**0.66**	< .0595	< .0595	< .0463	< .059	< .0819	< .0487	< .0819	< .235	**0.067**	< .0663	< .0308	< .0556	< .049
				VMW-02-(55)-091008 [2]		55	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	**0.048**	< .067	0.18	< .0562	< .0495
				VMW-02-(80)-091008 [2]		80	< .0487	< .0487	< .0219	< .0595	< .0595	< .0463	< .059	< .0819	< .0487	< .0819	< .235	< .0316	< .0663	< .0308	< .0556	< .049
				DUP2-091008 [2]	VMW-02-(80)-091008	80	< .0477	< .0477	< .0214	< .0583	< .0583	< .0453	< .056	< .0778	< .0477	< .0778	< .23	< .031	< .065	< .0302	< .0545	< .048
				VMW-03-(13)-090908[2]		13	< .00492	< .00492	< .00221	< .00601	**0.072**	< .00467	< .0059	< .00819	< .00492	< .00819	0.04	< .00319	< .0067	0.022	0.0067	< .00495
				VMW-03-(35)-090908[2]		35	< .0492	< .0492	< .0221	< .0601	**0.066**	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
				VMW-03-(55)-090908[2]		55	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	0.053	< .0562	< .0495
				VMW-03(80)091908 [2]		80	0.054	0.014	< .0011	< .00301	**0.09**	0.084	0.11	0.009	0.01	0.0061	0.086 J	0.012	< .00335	< .00156	< .00281	< .00247
				VMW-04-(13)-091008[2]		13	< .0477	< .0477	< .0214	< .0583	< .0583	< .0453	< .056	< .0778	< .0477	< .0778	< .23	< .031	< .065	< .0302	< .0545	< .048
				VMW-04-(50)-091008[2]		50	< .0482	< .0482	< .0216	< .0589	< .0589	< .0458	< .059	< .0819	< .0482	< .0819	< .233	< .0313	< .0657	< .0305	< .0551	< .0485
				VMW-04(75)-091108[2]		75	< .0492	< .0492	< .0221	< .0601	< .0601	< .0467	< .059	< .0819	< .0492	< .0819	< .238	< .0319	< .067	< .0311	< .0562	< .0495
Sitewide[7]	Ambient Air	Fab West Building [3]	Fab West Building	AA02-092506			0.011	< .005	< .0022	< .0061	< .0061	< .0047	0.23 D2	< .0083	0.01	< .0083	0.17 D2	< .0032	< .0068	< .0032	0.0097	< .005
		Corsicana Building [4]	Corsicana Building	AA01-092506			< .0025	< .0025	< .0011	< .0031	0.0067	< .0024	< .003	< .0042	< .0022	< .0042	0.031	< .0016	< .0034	0.0016	< .0028	0.0038
		GranQuartz Building [5]	GranQuartz Building	AA01-092106			0.0044	< .0025	< .0011	< .0031	< .0031	0.0062	0.0051	< .0042	< .0022	< .0042	0.1	0.0027	< .0034	< .0016	0.0034	0.0045
		AdobeAir Building [6]	AdobeAir Building	AA01-(0)-09192006			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	0.027	< .0016	< .0034	< .0016	< .0028	0.0035
		Outside north of SG-102	AdobeAir Building	AA-IA-AA-02052009			< .00246	< .00246	< .0011	< .00301	< .00301	< .00234	< .00295	< .0041	< .00246	< .0041	< .0119	< .0016	< .00335	< .00156	< .00281	0.0029
		Outside north of SG-102	AdobeAir Building	AA-IA-AA1-082109			< .0012	< .0012	NA	< .0012	0.0087	NA	0.016	< .001	< .0012	< .00082	NA	< .000015	< .001	< .00078	0.0015 J	0.0025
		Outside south of SG-41	AdobeAir Building	AA-IA-AA2-082109			< .0012	< .0012	NA	< .0012	0.0088	NA	0.016	< .001	< .0012	< .00082	NA	< .000015	< .001	< .00078	0.0015 J	0.0026
	Field Blanks	SG-83	Phase II Soil Gas Investigation	FB01-(0)-12052007			0.1	0.046	< .0011	< .0031	< .0031	0.046	< .003	< .0042	0.036	< .0042	0.048	**0.055**	< .0034	< .0016	< .0028	0.0036
		SG-70		FB01-(0)-12102007			0.011	0.0065	< .0011	< .0031	0.0038	< .0024	< .003	< .0042	0.0071	< .0042	0.013	< .0016	< .0034	< .0016	< .0028	0.0039
		SG-78		FB01-(0)-12112007			0.0041	< .0025	< .0011	< .0031	< .0031	0.0036	< .003	< .0042	< .0022	< .0042	0.039	0.0027	< .0034	< .0016	< .0028	0.004
		SG-98	Phase III Soil Gas Inv.	FB-01212008			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	0.027	< .0016	< .0034	< .0016	< .0028	0.0035
		VMW-01 Initial Sample	Semi-Annual Soil Vapor Sampling at VMW-01	FB-03172008			< .0025	< .0025	< .0011	< .0031	0.0031	< .0024	< .003	< .0042	< .0022	< .0042	0.013	< .0016	< .0034	< .0016	< .0028	0.0029
		VMW-01 Purge Test		FB-090908			< .00246	< .00246	< .0011	< .00301	0.016	< .00234	< .00295	< .0041	< .00246	< .0041	0.043	< .0016	< .00335	< .00156	< .00281	0.0033
		VMW-01		FB-033108			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .065	< .0016	< .0034	< .0016	< .0028	0.0034
				FB-091008			0.0025	< .00246	< .0011	< .00301	< .00301	< .00234	< .00295	< .0041	< .00246	< .0041	0.038	< .0016	< .00335	< .00156	< .00281	0.0033
				FB-03192009			0.004	< .00246	< .0011	< .00301	0.01	0.0042	< .00295	< .0041	< .00246	< .0041	0.05	0.002	< .00335	< .00156	< .00281	0.0034
				FB-091009			< .00246	< .00246	< .0011	< .00301	0.0084	0.0026	0.012	< .0041	< .00246	< .0041	0.038	0.0019	< .00335	< .00156	< .00281	< .00247
				AA-03172010			0.0069	0.0019 J	< .0011	< .00301	< .00301	0.0044	0.0035	< .0041	0.0024 J	< .0041	0.048	0.012	< .00335	< .00156	0.0013 J	0.0025
				FB-09092010			< .0025	< .0025	< .0011	< .003	< .003	0.0043	0.0038	< .0041	< .0025	< .0041	0.031	< .0016	< .0034	< .0016	< .0028	< .0025
	Trip Blanks	Phase I Soil Gas Investigation	Trip Blanks	TB01-(0)-09192006			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB01-092006			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB01-092106			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB01-(0.0)-092206			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB01-092506			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB02-092506			< .0025	< .0025	< .0011	< .0031	0.0045	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB03-092506			0.004	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
		Phase II Soil Gas Investigation		TB01-(0)-12042007			0.0039	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB01-(0)-12102007			0.006	0.0031	< .0011	< .0031	0.0073	< .0024	< .003	< .0042	0.0044	< .0042	0.039	< .0016	< .0034	< .0016	< .0028	< .0025
		Phase III Soil Gas Inv		TB-01212008			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
		VMW-01		TB-03172008			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	< .012	< .0016	< .0034	< .0016	< .0028	< .0025
				TB-033108			< .0025	< .0025	< .0011	< .0031	< .0031	< .0024	< .003	< .0042	< .0022	< .0042	0.013	< .0016	< .0034	< .0016	< .0028	< .0025
				TB-090908			< .00246	< .00246	< .0011	< .00301	< .00301	< .00234	< .00295	< .0041	< .00246	< .0041	< .0119	< .0016	< .00335	< .00156	< .00281	< .00247
				TB-03192009			< .00246	< .00246	< .0011	< .00301	**0.06**	< .00234	< .00295	< .0041	< .00246	< .0041	< .0119	< .0016	< .00335	< .00156	< .00281	< .00247
				TB-091609			< .00246	< .00246	< .0011	< .00301	< .00301	< .00234	< .00295	< .0041	< .00246	< .0041	< .0119	< .0016	< .00335	< .00156	< .00281	< .00247
				Trip Blank (03-17-2010)			0.00079 J	< .00246	< .0011	< .00301	< .00301	< .00234	< .00295	< .0041	< .00246	< .0041	< .0119	< .0016	< .00335	< .00156	< .00281	< .00247
				TB-09092010			< .0025	< .0025	< .0011	< .003	< .003	< .0023	< .003	< .0041	< .0025	< .0041	< .012	< .0016	< .0034	< .0016	< .0028	< .0025

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-2 Other Constituents Detected in Soil Vapor Samples
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Sample Information						Other Contaminants (mg/m3)															
Sample Description	Sample Location	Potential Source Area	Sample ID	Parent Sample	Depth (Feet bgs)	Chloroform	Chloro-Methane	Cyclohexane	Dichloro-Methane	Ethyl Acetate	Ethylbenzene	Heptane	Hexane	m,p-Xylene	Methyl tert-butyl ether	o-Xylene	Propene	Styrene (Monomer)	Tetra-Hydrofuran	Toluene	Vinyl Acetate
* Calculated Residential Soil Vapor Screening Level						0.011	9.4	630	0.52	NE	0.097	NE	73	10 [1]	0.94	10 [1]	310	100	NE	520	21
*Calculated Industrial Soil Vapor Screening Level						0.053	39	2600	2.6	NE	0.49	NE	310	44 [1]	4.7	44 [1]	1300	440	NE	2200	88
Northern Portion	Soil Vapor	AdobeAir Warehouse - Outside (Northwest) - SVE Pilot Test Baseline, Vapor Monitoring Well Samples	Former 1,000 gallon concrete structure and suspected 10,000 gallon USTs	VMW-02(10)-091108 [2]		10	< .0488	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .118	< .0377	< .0352
				VMW-02(40)091008 [2]		40	**0.083**	< .0204	< .0341	< .0344	< .0357	< .043	< .0406	< .0349	0.19	< .0721	0.082	2.9	< .0422	< .118	< .0373	< .0349
				VMW-02-(55)-091008 [2]		55	**0.22**	< .0206	< .0344	< .0347	< .036	< .0434	< .041	0.07	< .0868	< .0721	< .0434	0.46	< .0426	< .118	0.045	< .0352
				VMW-02-(80)-091008 [2]		80	**0.32**	< .0204	< .0341	< .0344	< .0357	< .043	< .0406	0.049	< .0868	< .0721	< .043	0.38	< .0422	< .118	< .0373	< .0349
				DUP2-091008 [2]	VMW-02-(80)-091008	80	**0.32**	< .02	< .0334	< .0337	< .035	< .0421	< .0398	0.046	< .0825	< .0685	< .0421	0.52	< .0413	< .115	< .0366	< .0342
				VMW-03-(13)-090908 [2]		13	**0.025**	< .00206	< .00344	< .00347	< .0036	< .00434	< .0041	< .00352	< .00868	< .00721	< .00434	0.0029	< .00426	< .0118	< .00377	< .00352
				VMW-03-(35)-090908 [2]		35	< .0488	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	0.62	< .0426	< .118	< .0377	< .0352
				VMW-03-(55)-090908 [2]		55	< .0488	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	0.57	< .0426	< .118	< .0377	< .0352
				VMW-03(80)091908 [2]		80	< .00244	0.0016	0.0069	0.002	< .0018	0.012	0.0053	< .00176	< .00434	< .00361	0.012	< .000861	0.006	0.11	0.049	< .00176
				VMW-04-(13)-091008 [2]		13	< .0474	< .02	< .0334	< .0337	< .035	< .0421	< .0398	< .0342	< .0825	< .0685	< .0421	0.026	< .0413	< .115	< .0366	< .0342
				VMW-04-(50)-091008 [2]		50	**0.17**	< .0202	< .0337	< .034	< .0353	< .0426	< .0402	< .0345	< .0868	< .0721	< .0426	< .0169	< .0417	< .115	2.3	< .0345
				VMW-04(75)-091108 [2]		75	**0.25**	< .0206	< .0344	< .0347	< .036	< .0434	< .041	< .0352	< .0868	< .0721	< .0434	< .0172	< .0426	< .121	< .0377	< .0352
Sitewide [7]	Ambient Air	Fab West Building [3]	Fab West Building	AA02-092506			< .005	< .0021	< .0035	0.0078	< .0037	0.01	0.075	< .0036	0.035	< .0073	0.011	< .0018	< .0043	< .012	0.22 D2	< .0036
		Corsicana Building [4]	Corsicana Building	AA01-092506			< .0025	0.0011	< .0017	0.006	< .0018	< .0022	0.0032	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	0.0042	< .0018
		GranQuartz Building [5]	GranQuartz Building	AA01-092106			< .0025	0.0011	0.002	0.0021	< .0018	0.0033	0.0029	0.0032	0.01	< .0037	0.0033	0.011	0.0056	< .006	0.017	< .0018
		AdobeAir Building [6]	AdobeAir Building	AA01-(0)-09192006			< .0025	0.0012	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	0.0046	< .0018
		Outside north of SG-102	AdobeAir Building	AA-IA-AA-02052009			< .002	0.0013	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	0.002	< .00176
		Outside north of SG-102	AdobeAir Building	AA-IA-AA1-082109			0.000069	0.0013 J	NA	0.0004 J	NA	< .00065	NA	NA	< .0013	< .00072	< .00065	NA	< .00085	NA	0.0048	< .0007
		Outside south of SG-41	AdobeAir Building	AA-IA-AA2-082109			0.00008	0.0014 J	NA	0.015	NA	< .00065	NA	NA	< .0013	< .00072	< .00065	NA	< .00085	NA	0.0053	< .0007
	Field Blanks	SG-83	Phase II Soil Gas Investigation	FB01-(0)-12052007			< .0025	0.0013	0.027	0.0018	0.0073	0.039	0.024	0.039	0.19	< .0037	0.084	< .00088	0.0048	< .006	0.18	< .0018
		SG-70		FB01-(0)-12102007			< .0025	0.0015	< .0017	< .0018	< .0018	0.0028	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	0.0029	< .006	0.0019	< .0018
		SG-78		FB01-(0)-12112007			< .0025	0.0015	0.0029	< .0018	< .0018	0.0031	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	0.003	< .006	0.0065	< .0018
		SG-98	Phase III Soil Gas Inv.	FB-01212008			< .0025	0.0013	< .0017	0.0064	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	0.0034	< .0018
		VMW-01 Initial Sample	Semi-Annual Soil Vapor Sampling at VMW-01	FB-03172008			< .0025	0.0011	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
		VMW-01 Purge Test		FB-090908			< .00244	< .00103	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	< .00188	< .00176
		VMW-01		FB-033108			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				FB-091008			< .00244	0.0012	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	0.0031	< .00213	< .0059	0.003	< .00176
				FB-03192009			< .00244	0.0016	0.0034	0.014	0.02	< .00217	0.0024	0.0039	0.0052	< .00361	< .00217	0.0034	< .00213	< .0059	0.0087	< .00176
				FB-091009			< .00244	< .00103	< .00172	0.0033	< .0018	< .00217	< .00205	0.0026	< .00434	< .00361	< .00217	0.77	< .00213	< .0059	0.0032	< .00176
				AA-03172010			< .00244	0.0011	0.0024	0.00056 J	< .0018	0.0065	0.0018 J	0.0039	0.023	0.0061	0.0082	< .000861	< .00213	< .0059	0.064	< .00176
				FB-09092010			< .0024	< .001	< .0017	< .0017	< .0018	< .0022	< .0021	< .0018	< .0043	< .0036	< .0022	< .00086	< .0021	< .0059	0.0075	< .0018
	Trip Blanks	Phase I Soil Gas Investigation	Trip Blanks	TB01-(0)-09192006			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB01-092006			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB01-092106			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB01-(0.0)-092206			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB01-092506			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB02-092506			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	0.0023	< .0018
				TB03-092506			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	0.0046	< .0018
		Phase II Soil Gas Investigation		TB01-(0)-12042007			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB01-(0)-12102007			< .0025	< .001	< .0017	0.0071	0.004	< .0022	< .0021	0.0023	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
		Phase III Soil Gas Inv		TB-01212008			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
		VMW-01		TB-03172008			< .0025	< .001	< .0017	< .0018	< .0018	< .0022	< .0021	< .0018	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB-033108			< .0025	< .001	< .0017	0.0042	< .0018	< .0022	< .0021	0.014	< .0044	< .0037	< .0022	< .00088	< .0022	< .006	< .0019	< .0018
				TB-090908			< .00244	< .00103	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	< .00188	< .00176
				TB-03192009			< .00244	< .00103	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	< .00188	< .00176
				TB-091609			< .00244	< .00103	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	< .00188	< .00176
				Trip Blank (03-17-2010)			< .00244	< .00103	< .00172	< .00174	< .0018	< .00217	< .00205	< .00176	< .00434	< .00361	< .00217	< .000861	< .00213	< .0059	< .00188	< .00176
				TB-09092010			< .0024	< .001	< .0017	< .0017	< .0018	< .0022	< .0021	< .0018	< .0043	< .0036	< .0022	< .00086	< .0021	< .0059	< .0019	< .0018

Notes

All units are in mg/m3 (milligrams per cubic meter)
bgs - below ground surface
NE - Not Established
SG - Soil gas
< - Constituent not detected at or above method reporting limit.
D2 - Sample diluted
FD - Field duplicate
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for residential use only.
P1, P3, and P7 - Indicate samples with either 1 volume, 3 volumes, or 7 volume purges for the purge test.
Bold - Concentration exceeds the Calculated Soil Vapor Screening Levels for either residential or industrial usage.
U - Analyte detected in ambient air sample or trip blank.
UB - Compound considered non-detect at the listed value due to associated blank contamination.
J - Poor field duplicate precision
UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.
NA - Analyte not analyzed
R - Data rejected due to poor duplicate precision
V2 - Indicates the second attempt for purge volume test, event for the same borehole.
AA - Ambient Air
TB - Trip blank
*Calculated Soil Vapor Screening Levels for soil vapor residential and industrial use scenarios were calculated using USEPA indoor air RSL (November 2011) divided by 0.01, where 0.01 is the deep soil vapor attenuation factor (>5 feet below ground surface).

1 - All Xylene Isomers have the same RSL.
2 - Samples also used for the Baseline Soil Vapor Sampling Event.
3 - Ambient Air sample can only be used to evaluate SG-61 through SG-63.
4 - Ambient Air sample can only be used to evaluate SG-57 through SG-60.
5 - Ambient Air sample can only be used to evaluate SG-54 through SG-56.
6 - Ambient Air sample can only be used to evaluate SG-1 through SG-34.
7 - Sitewide samples may be associated with samples collected either in the Northern or Southern Portions of the Facility, or may be associated with samples collected in both (e.g., trip blanks).

Table A-3 Historical Groundwater Analytical Results (Other Detected Constituents)
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Location ID	Date	Sample ID	Acetone	Bromo-dichloromethane	CFC-12	Chlorobenzene	momethane (Methylene chloride)	Chloroform	MEK	MTBE	Toluene	Tribromomethane	Xylenes, total	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury
		MCL	NE	NE	NE	NE	NE	NE	NE	NE	1,000	80	10,000	0.01	2	0.005	0.1	0.015	0.002
		AWQS	NE	80(1)	NE	100	NE	80(1)	NE	NE	1,000	80(1)	10,000	0.05	2	0.005	0.1	0.015	0.002
		Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	1/14/1992	MW-1 (duplicate)	NA	< 0.2	< 0.2	< 0.5	<2.0	0.6	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	NA	NA	NA
	1/14/1992	Duplicate (MW-1)	NA	< 0.2	< 0.2	< 0.5	<2.0	0.5	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.041	0.007	NA
	1/14/1992	MW01-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.6	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.041	0.007	NA
MW-1	4/30/1992	MW01-04301992	NA	0.3	< 0.2	< 0.5	<2.0	2.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	7/20/1992	MW01-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	1.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	10/27/1992	MW01-10271992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.8	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	9/7/1999	MW01-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0124	0.102	< 0.005	< 0.01	< 0.005	0.000438
	1/14/1992	MW02-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.4	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.064	0.007	NA
	1/14/1992	MW-2	NA	< 0.2	< 0.2	< 0.5	<2.0	0.6	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	NA	NA	NA
	4/30/1992	MW02-04301992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.5	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
MW-2	7/20/1992	MW02-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	10/27/1992	MW02-10271992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.2	NA	NA	0.7	< 0.2	2.0	NA	NA	NA	< 0.01	< 0.002	NA
	12/1/1994	MW02-12011994	<50	< 0.2	< 0.2	< 0.5	< 0.2	0.7	NA	NA	< 0.5	< 0.5	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	9/7/1999	MW02-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0111	0.0945	< 0.005	< 0.01	< 0.005	< 0.0002
	9/9/2002	AA-MW-2	NA	< 1	< 1	< 1	0.5	0.5	4	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/14/1992	MW03-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.052	0.012	NA
	1/14/1992	MW-3 (duplicate)	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	NA	NA	NA
	4/30/1992	MW03-04301992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	7/20/1992	MW03-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	10/27/1992	MW03-10271992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.2	NA	NA	< 0.5	< 0.2	0.9	NA	NA	NA	< 0.01	< 0.002	NA
MW-3	12/1/1994	MW03-12011994	<50	< 0.2	0.6	< 0.5	<0.2	< 0.5	NA	NA	< 0.5	< 0.5	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	9/7/1999	MW03-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0107	0.14	< 0.005	< 0.01	< 0.005	< 0.0002
	9/29/2005	MW3-092905	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2006	MW0303282006	<10	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	<2.5	< 0.5	< 0.5	< 1	NA	NA	NA	NA	NA	NA	NA
	3/29/2007	MW303292007	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/29/2007	DUP03292007*	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/14/1992	MW04-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.5	NA	NA	< 0.5	<0.2	< 0.5	NA	NA	NA	0.029	0.004	NA
	1/14/1992	MW-4 (duplicate)	NA	< 0.2	< 0.2	< 0.5	<2.0	1.3	NA	NA	< 0.5	<0.2	< 0.5	NA	NA	NA	NA	NA	NA
	4/30/1992	MW04-04301992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.9	NA	NA	< 0.5	<0.2	< 0.5	NA	NA	NA	0.013	<0.002	NA
	4/30/1992	MW7-04301992 (MW-4 Dup)	NA	<0.2	< 0.2	< 0.5	<2.0	1.0	NA	NA	< 0.5	NA	< 0.5	NA	NA	NA	0.014	<0.002	NA
	7/20/1992	MW04-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	2.5	NA	NA	< 0.5	NA	< 0.5	NA	NA	NA	0.012	<0.002	NA
	7/20/1992	MW07-07201992 (MW-4 Dup)	NA	<0.2	< 0.2	<0.5	<2.0	2.2	NA	NA	< 0.5	NA	< 0.5	NA	NA	NA	<0.01	<0.002	NA
	10/27/1992	MW04-10271992	NA	< 0.2	< 0.2	1.7	<2.0	1.6	NA	NA	< 0.5	NA	< 0.5	NA	NA	NA	<0.01	<0.002	NA
	10/27/1992	MW07-10271992 (MW-4 Dup)	NA	<0.2	< 0.2	1.6	<2.0	1.8	NA	NA	<0.5	NA	<0.5	NA	NA	NA	<0.01	<0.002	NA
	12/1/1994	MW04-12011994	<50	< 0.2	< 0.2	< 0.5	<0.2	0.7	NA	NA	< 0.5	0.5	< 0.5	NA	NA	NA	<0.01	<0.002	NA
	9/7/1999	MW04-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0162	0.0203	<0.005	0.0216	<0.005	0.000349
	9/29/2005	MW4-092905	<20	< 1	< 1	< 1	< 1	1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2006	FD0103282006	<10	< 0.5	< 0.5	< 0.5	< 0.5	0.79	<2.5	< 0.5	< 0.5	< 1	NA	NA	NA	NA	NA	NA	NA
MW-4	3/28/2006	MW0403282006	<10	< 0.5	< 0.5	< 0.5	< 0.5	0.79	<2.5	< 0.5	< 0.5	< 1	NA	NA	NA	NA	NA	NA	NA
	3/29/2007	MW403292007	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2008	MW4-03282008	<20	< 1	< 1	< 1 V1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/16/2008	MW4-09162008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/18/2009	DUP-03182009	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/18/2009	MW4-03182009	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/9/2009	MW4-090909	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/16/2010	MW4-03162010	<20	< 1	< 1	< 1	<2	1.5	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	4/15/2010	MW4-04152010	<20	< 1	< 1	< 1	<2	1.5	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	9/8/2010	MW4-09082010	<20	< 1	< 1	< 1	<2	1.6	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	9/8/2010	DUP-09082010	<20	< 1	< 1	< 1	<2	1.6	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	3/17/2011	MW4-03172011	< 20 U	< 1	< 1	< 1	<1	1.4	< 5	< 1	< 1	< 1	< 2	NA	NA	NA	NA	NA	NA
	3/17/2011	DUP-03172011	< 20 U	< 1	< 1	< 1	<1	1.4	< 5	< 1	< 1	< 1	< 2	NA	NA	NA	NA	NA	NA

Notes
CFC-12 = Dichlorodifluoromethane
MEK = methyl ethyl ketone
MTBE = methyl-tertiary butyl ether
MCL = USEPA Maximum Contaminant Level
NE= Not established
AWQS = Arizona Aquifer Water Quality Standards

ug/L = micrograms per liter
mg/L = milligrams per liter
NA = Not analyzed
< = Constituent not detected above laboratory method reporting limit.
AA = Groundwater sample IDs beginning with AA denote "Adobe Air".
* = Duplicate sample, the parent sample is MW303292007.

(1) Total trihalomethane (TTHM) standard is exceeded when the sum of the four compounds bromodichloromethane, dibromochloromethane, bromoform, and chloroform exceeds 80 µg/L, as a rolling annual average.
V1 = Calibration verification: CCV recovery was above method acceptance limits.
This target analyte was not detected in the sample.
Blue values indicate exceedance of both MCL and AWQS.
Red values indicate exceedance of lowest value, either MCL or AWQS.

Table A-3 Historical Groundwater Analytical Results (Other Detected Constituents)
Motorola 52nd Street Superfund Site
500 South 15th Street Facility, Phoenix, Arizona

Location ID	Date	Sample ID	Acetone	Bromo-dichloromethane	CFC-12	Chlorobenzene	momethane (Methylene chloride)	Chloroform	MEK	MTBE	Toluene	Tribromomethane	Xylenes, total	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury
		MCL	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**1,000**	**80**	**10,000**	**0.01**	**2**	**0.005**	**0.1**	**0.015**	**0.002**
		AWQS	**NE**	**80(1)**	**NE**	**100**	**NE**	**80(1)**	**NE**	**NE**	**1,000**	**80(1)**	**10,000**	**0.05**	**2**	**0.005**	**0.1**	**0.015**	**0.002**
		Units	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
MW-5	1/14/1992	MW-5 (duplicate)	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	NA	NA	NA
	1/14/1992	MW05-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.4	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.107	0.016	NA
	4/30/1992	MW05-04301992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	7/20/1992	MW05-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	0.6	< 0.2	1.8	NA	NA	NA	< 0.01	< 0.002	NA
	10/27/1992	MW05-10271992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.2	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	9/7/1999	MW05-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0161	0.144	0.005	0.0124	< 0.005	0.000289
	9/9/2002	AA-MW-5	<4	< 1	< 1	< 1	< 1	< 1	<4	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
MW-6	1/14/1992	MW06-01141992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.4	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	0.105	0.016	NA
	1/14/1992	MW-6 (duplicate)	NA	< 0.2	< 0.2	< 0.5	<2.0	0.6	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	NA	NA	NA
	4/30/1992	MW06-04301992	NA	< 0.2	< 0.2	< 0.5	<2.0	< 0.5	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	7/20/1992	MW06-07201992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	10/27/1992	MW06-10271992	NA	< 0.2	< 0.2	< 0.5	<2.0	0.3	NA	NA	< 0.5	< 0.2	< 0.5	NA	NA	NA	< 0.01	< 0.002	NA
	9/7/1999	MW06-09071999	<100	< 5	< 10	< 5	< 5	< 5	<20	< 5	< 5	< 5	< 5	0.0123	0.131	< 0.005	< 0.01	< 0.005	0.000232
MW-7	1/22/2008	DUP-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW7-100-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW7-106-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW7-92-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2008	DUP-03282008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2008	MW7-03282008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/16/2008	DUP-09162008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/16/2008	MW7-09162008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/18/2009	MW7-03182009	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/8/2009	MW7-09082010	<20	< 1	< 1	< 1	<2	1.6	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	3/16/2010	DUP-03162010	<20	< 1	< 1	< 1	<2	1.2	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	3/16/2010	MW7-03162010	<20	< 1	< 1	< 1	<2	1.3	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	4/15/2010	MW7-04152010	<20	< 1	< 1	< 1	<2	1.1	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
	3/17/2011	MW7-03172011	< 20	< 1	< 1	< 1	< 1	1.2	< 5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA
MW-8	1/22/2008	MW8-106-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW8-92-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW8-99-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2008	MW8-03282008	<20	< 1	< 1	< 1 V1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/16/2008	MW8-09162008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/18/2009	MW8-03182009	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/9/2009	MW8-090909	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/16/2010	MW8-03162010	<20	< 1	< 1	< 1	< 1	< 1	<5	1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	4/15/2010	MW8-04152010	<20	< 1	< 1	< 1	< 1	< 1	<5	<1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/8/2010	MW8-09082010	<20	< 1	< 1	< 1	< 1	< 1	<5	<1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/17/2011	MW8-03172011	< 20	< 1	< 1	< 1	< 1	< 1	<5	<1	<1	<1	<2	NA	NA	NA	NA	NA	NA
MW-9	1/22/2008	MW9-107-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW9-92-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	1/22/2008	MW9-100-012208	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/28/2008	MW9-03282008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/16/2008	MW9-09162008	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/18/2009	MW9-03182009	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/9/2009	MW9-090909	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/16/2010	MW9-03162010	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	4/15/2010	MW9-04152010	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	9/8/2010	MW9-09082010	<20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
	3/17/2011	MW9-03172011	< 20	< 1	< 1	< 1	< 1	< 1	<5	< 1	< 1	< 1	<2	NA	NA	NA	NA	NA	NA

Notes

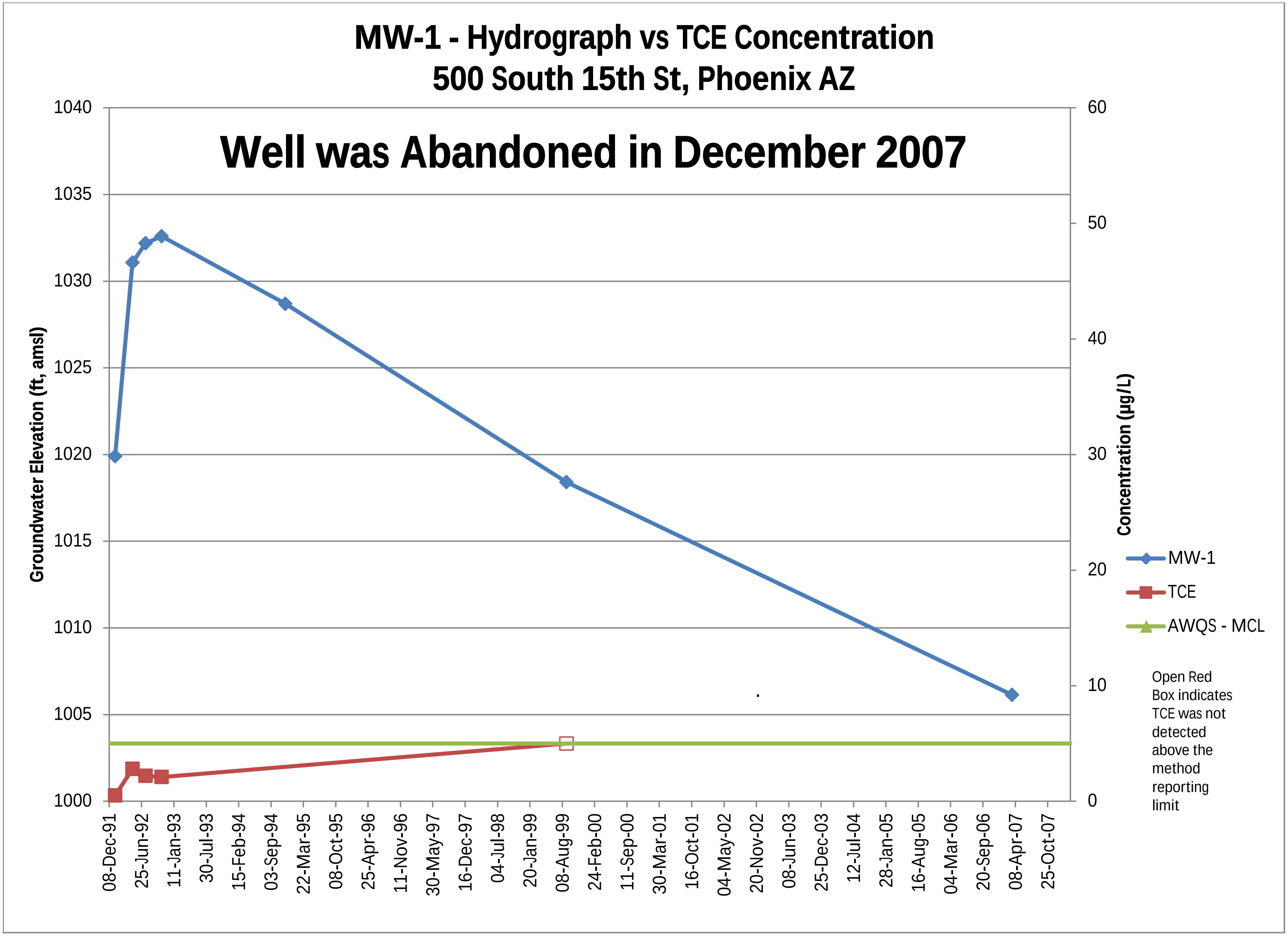
CFC-12 = Dichlorodifluoromethane
MEK = methyl ethyl ketone
MTBE = methyl-tertiary butyl ether
MCL = USEPA Maximum Contaminant Level
NE= Not established
AWQS = Arizona Aquifer Water Quality Standards

ug/L = micrograms per liter
mg/L = milligrams per liter
NA = Not analyzed
< = Constituent not detected above laboratory method reporting limit.
AA = Groundwater sample IDs beginning with AA denote "Adobe Air".
* = Duplicate sample, the parent sample is MW303292007.

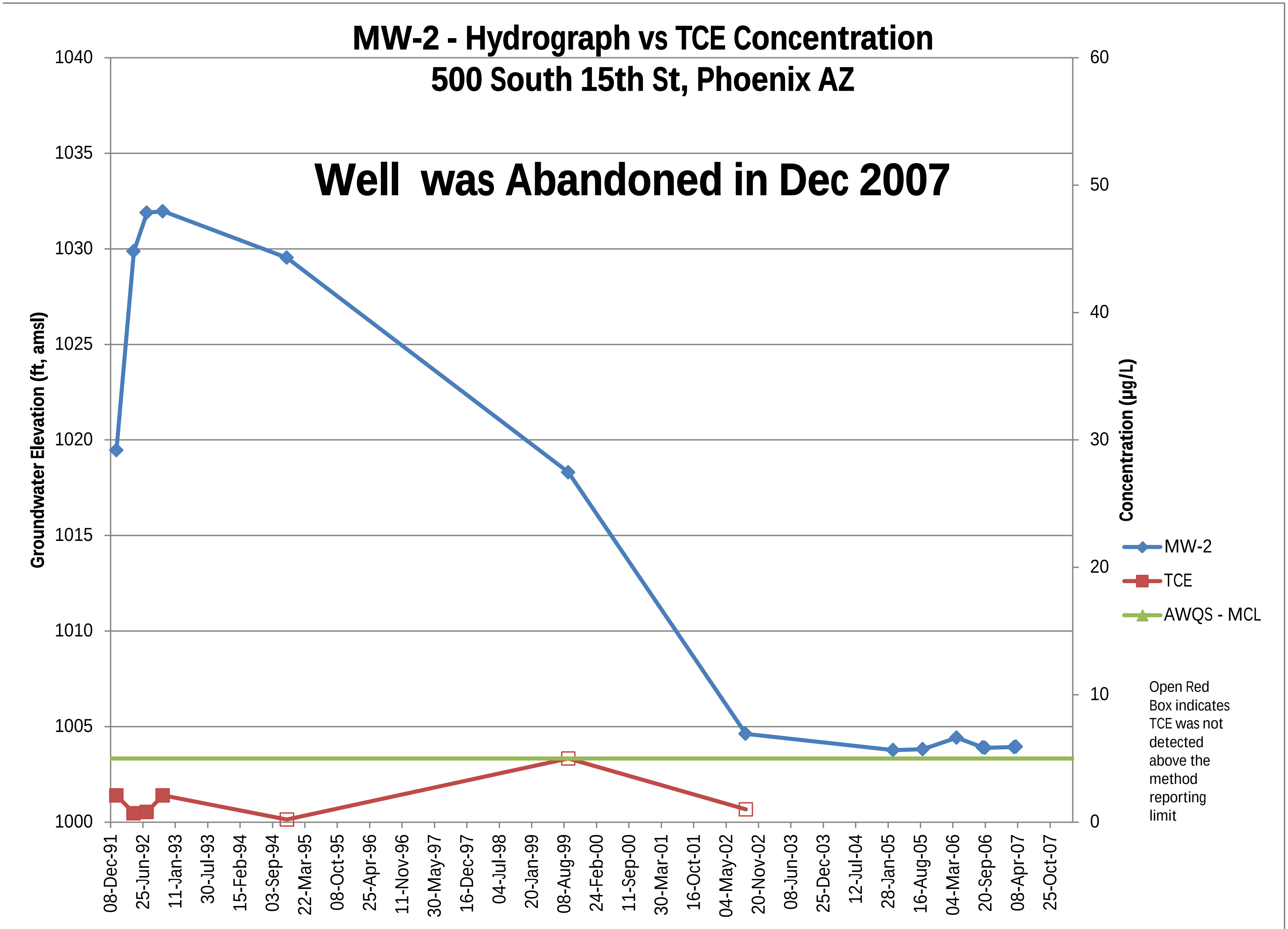
(1) Total trihalomethane (TTHM) standard is exceeded when the sum of the four compounds bromodichloromethane, dibromochloromethane, bromoform, and chloroform exceeds 80 µg/L, as a rolling annual average.
V1 = Calibration verification: CCV recovery was above method acceptance limits.
This target analyte was not detected in the sample.
Blue values indicate exceedance of both MCL and AWQS.
Red values indicate exceedance of lowest value, either MCL or AWQS.

Appendix B

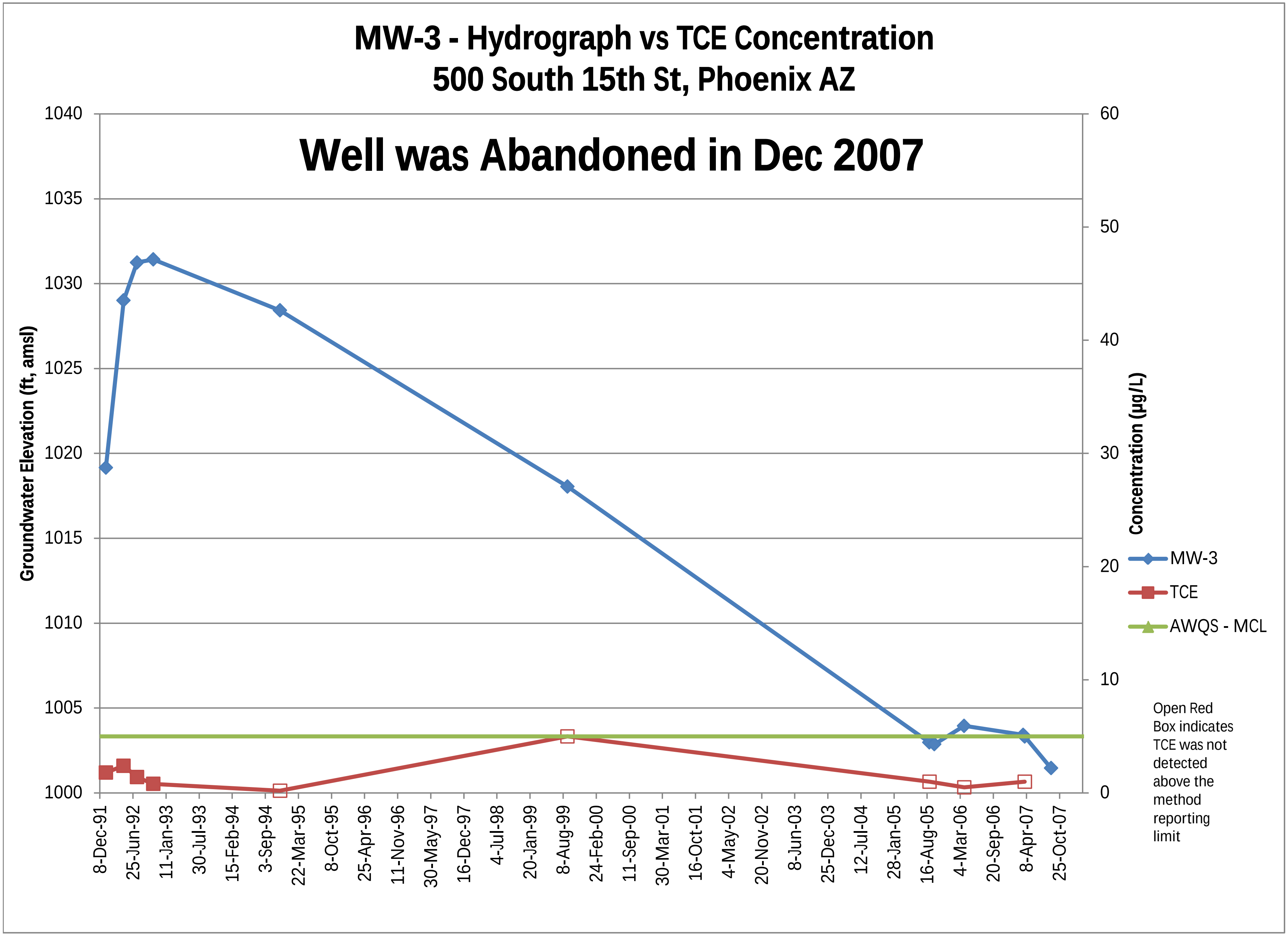
Hydrographs

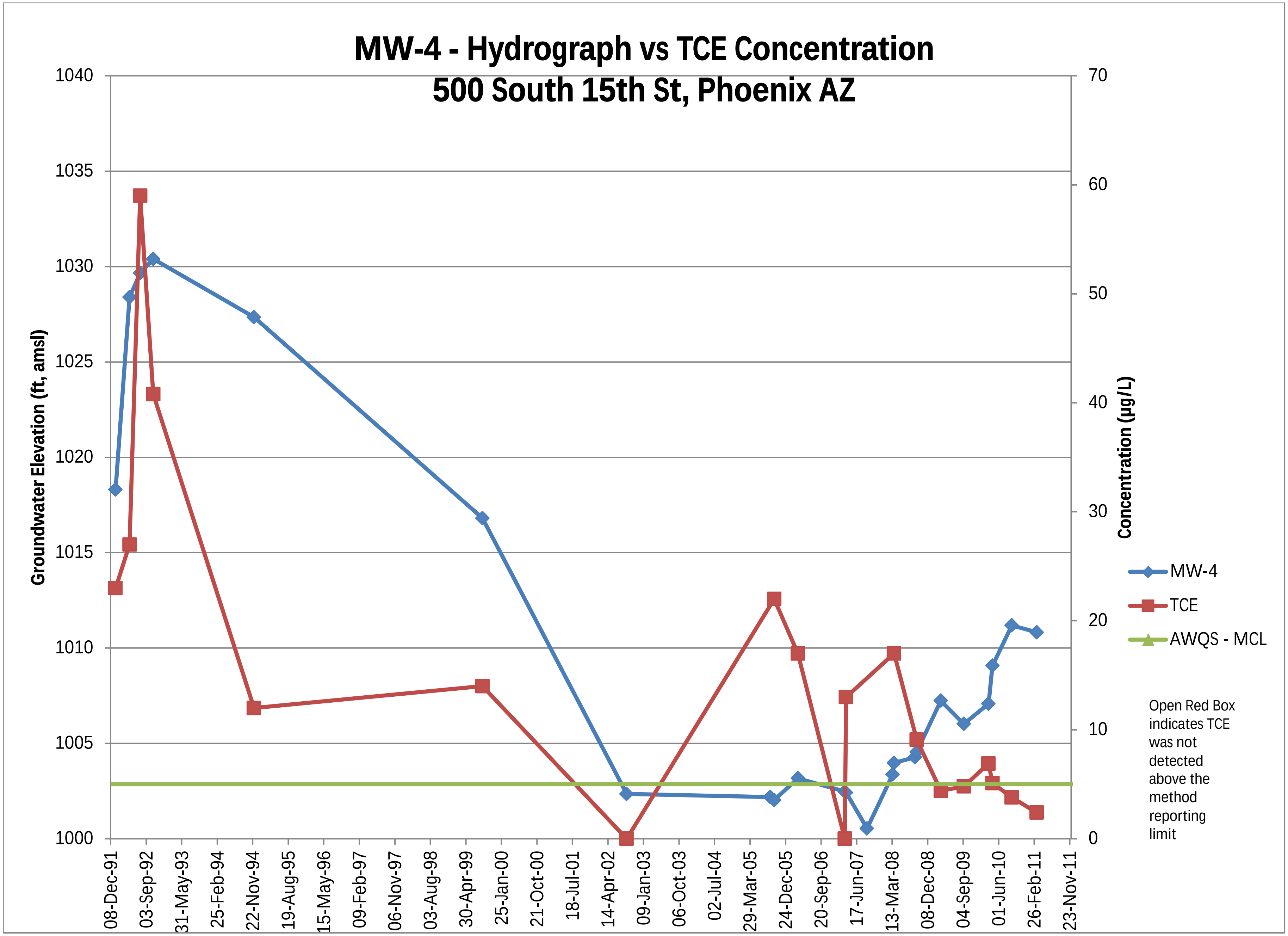


MW-1 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Well was Abandoned in December 2007
Groundwater Elevation (ft, amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
08-Dec-91
25-Jun-92
11-Jan-93
30-Jul-93
15-Feb-94
03-Sep-94
22-Mar-95
08-Oct-95
25-Apr-96
11-Nov-96
30-May-97
16-Dec-97
04-Jul-98
20-Jan-99
08-Aug-99
24-Feb-00
11-Sep-00
30-Mar-01
16-Oct-01
04-May-02
20-Nov-02
08-Jun-03
25-Dec-03
12-Jul-04
28-Jan-05
16-Aug-05
04-Mar-06
20-Sep-06
08-Apr-07
25-Oct-07
MW-1
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit

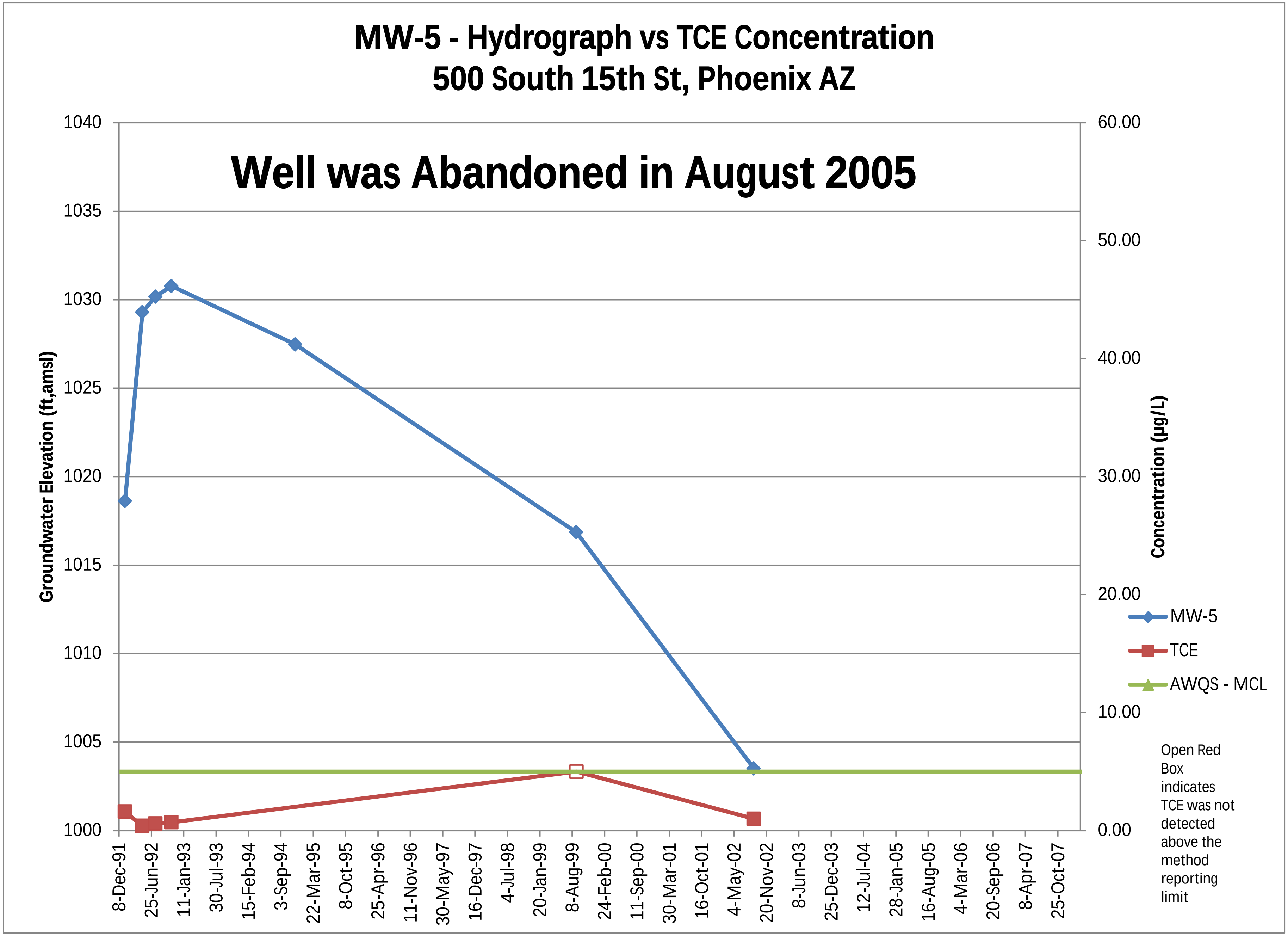


MW-2 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Well was Abandoned in Dec 2007
Groundwater Elevation (ft, amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
08-Dec-91
25-Jun-92
11-Jan-93
30-Jul-93
15-Feb-94
03-Sep-94
22-Mar-95
08-Oct-95
25-Apr-96
11-Nov-96
30-May-97
16-Dec-97
04-Jul-98
20-Jan-99
08-Aug-99
24-Feb-00
11-Sep-00
30-Mar-01
16-Oct-01
04-May-02
20-Nov-02
08-Jun-03
25-Dec-03
12-Jul-04
28-Jan-05
16-Aug-05
04-Mar-06
20-Sep-06
08-Apr-07
25-Oct-07
MW-2
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit

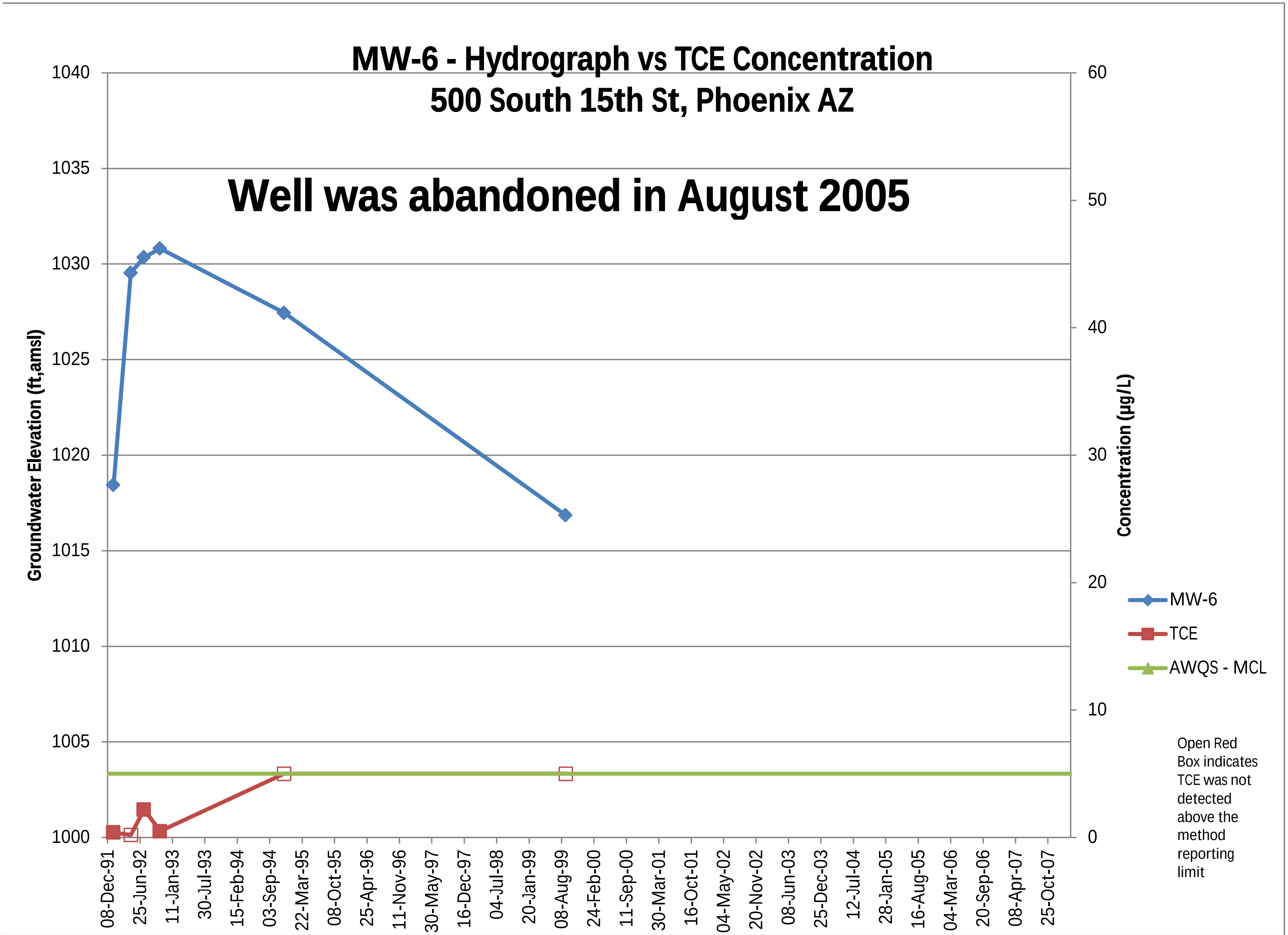

MW-3 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Well was Abandoned in Dec 2007
Groundwater Elevation (ft, amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
8-Dec-91
25-Jun-92
11-Jan-93
30-Jul-93
15-Feb-94
3-Sep-94
22-Mar-95
8-Oct-95
25-Apr-96
11-Nov-96
30-May-97
16-Dec-97
4-Jul-98
20-Jan-99
8-Aug-99
24-Feb-00
11-Sep-00
30-Mar-01
16-Oct-01
4-May-02
20-Nov-02
8-Jun-03
25-Dec-03
12-Jul-04
28-Jan-05
16-Aug-05
4-Mar-06
20-Sep-06
8-Apr-07
25-Oct-07
MW-3
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit



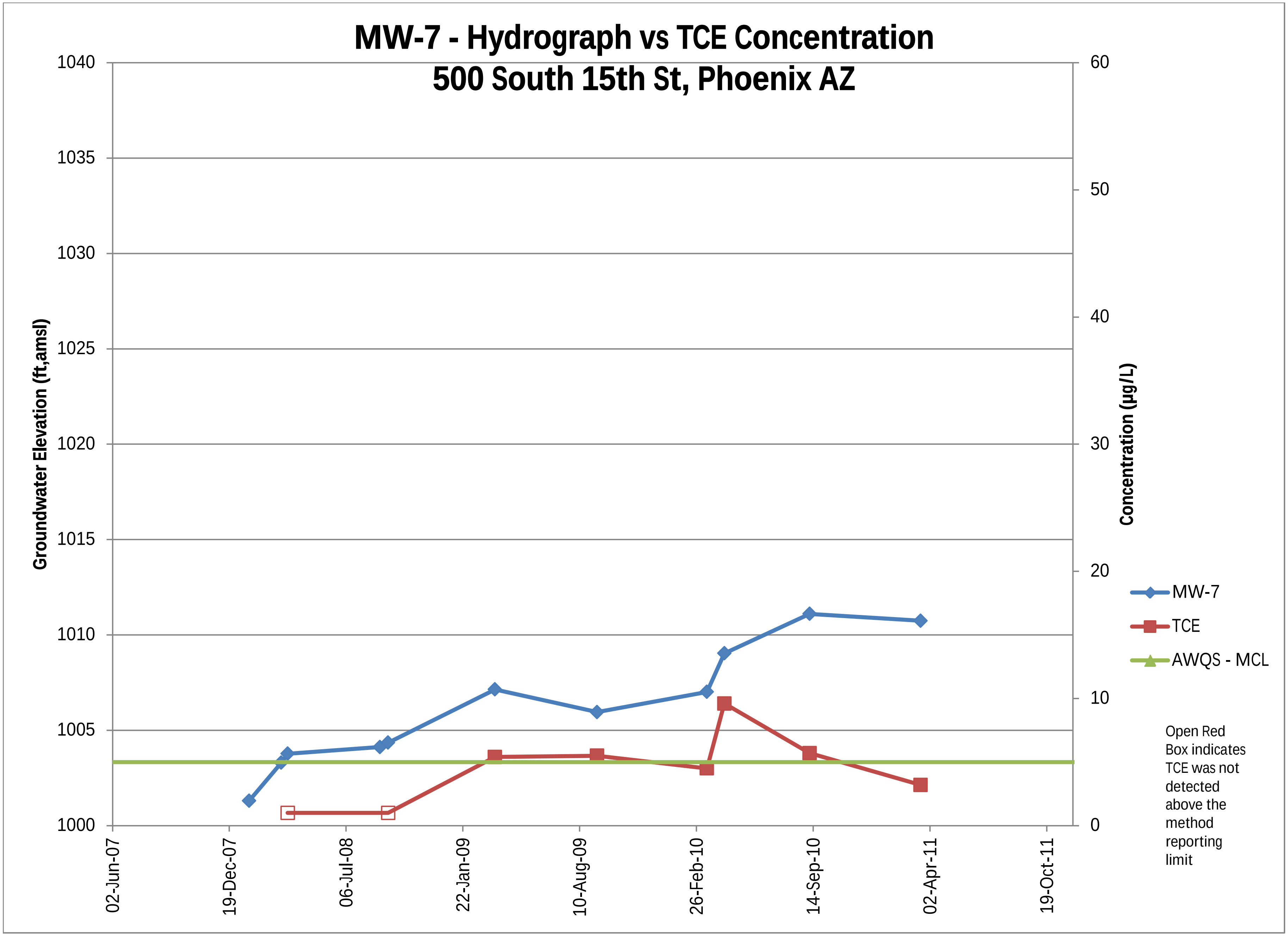
MW-4 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Groundwater Elevation (ft, amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
70
60
50
40
30
20
10
0
08-Dec-91
03-Sep-92
31-May-93
25-Feb-94
22-Nov-94
19-Aug-95
15-May-96
09-Feb-97
06-Nov-97
03-Aug-98
30-Apr-99
25-Jan-00
21-Oct-00
18-Jul-01
14-Apr-02
09-Jan-03
06-Oct-03
02-Jul-04
29-Mar-05
24-Dec-05
20-Sep-06
17-Jun-07
13-Mar-08
08-Dec-08
04-Sep-09
01-Jun-10
26-Feb-11
23-Nov-11
MW-4
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit



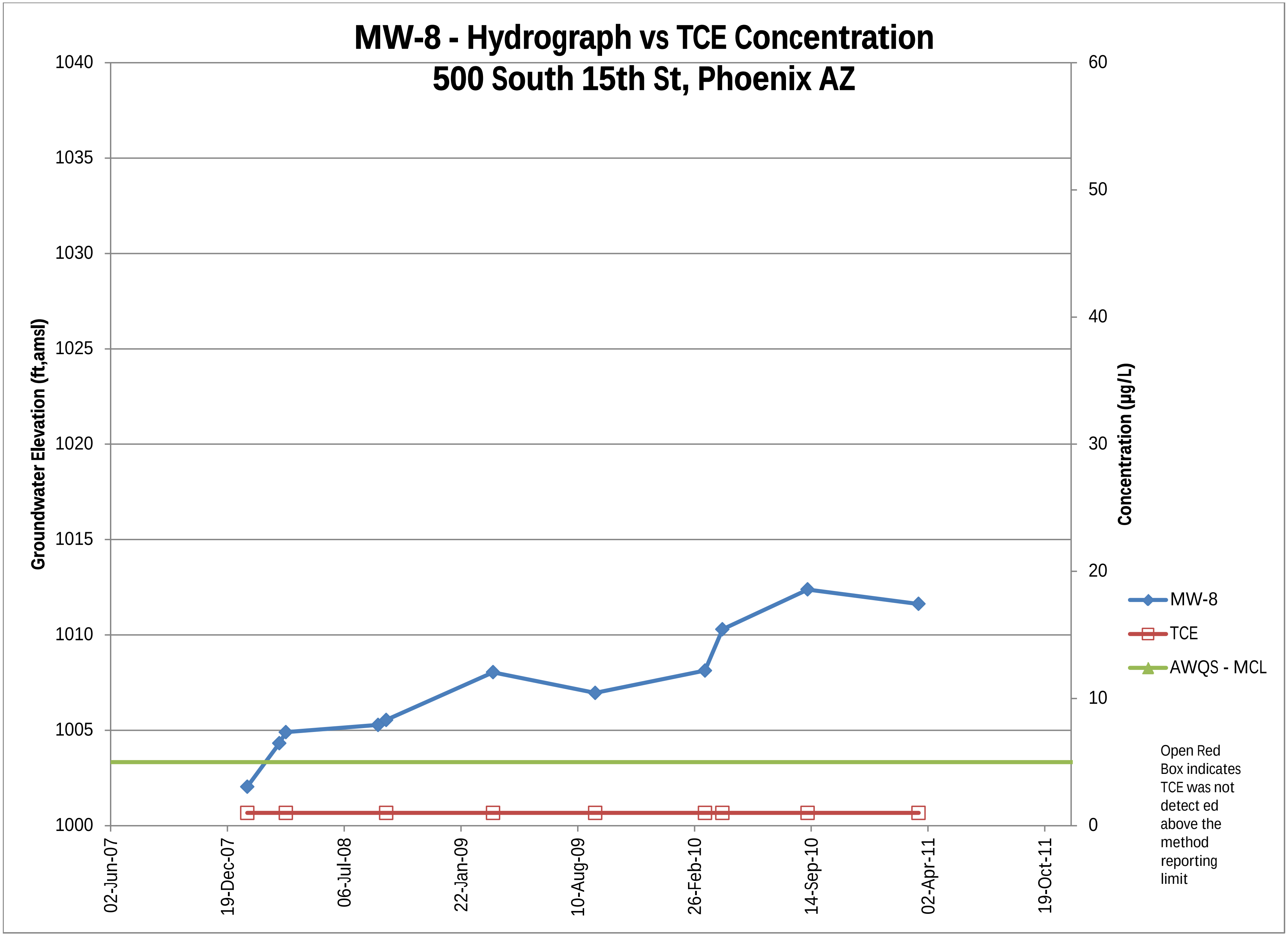
MW-5 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Well was Abandoned in August 2005
Groundwater Elevation (ft,amsl)
1040
1035
1030
1025
1020
1015
1010
1005
1000
Concentration (µg/L)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
8-Dec-91
25-Jun-92
11-Jan-93
30-Jul-93
15-Feb-94
3-Sep-94
22-Mar-95
8-Oct-95
25-Apr-96
11-Nov-96
30-May-97
16-Dec-97
4-Jul-98
20-Jan-99
8-Aug-99
24-Feb-00
11-Sep-00
30-Mar-01
16-Oct-01
4-May-02
20-Nov-02
8-Jun-03
25-Dec-03
12-Jul-04
28-Jan-05
16-Aug-05
4-Mar-06
20-Sep-06
8-Apr-07
25-Oct-07
MW-5
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit

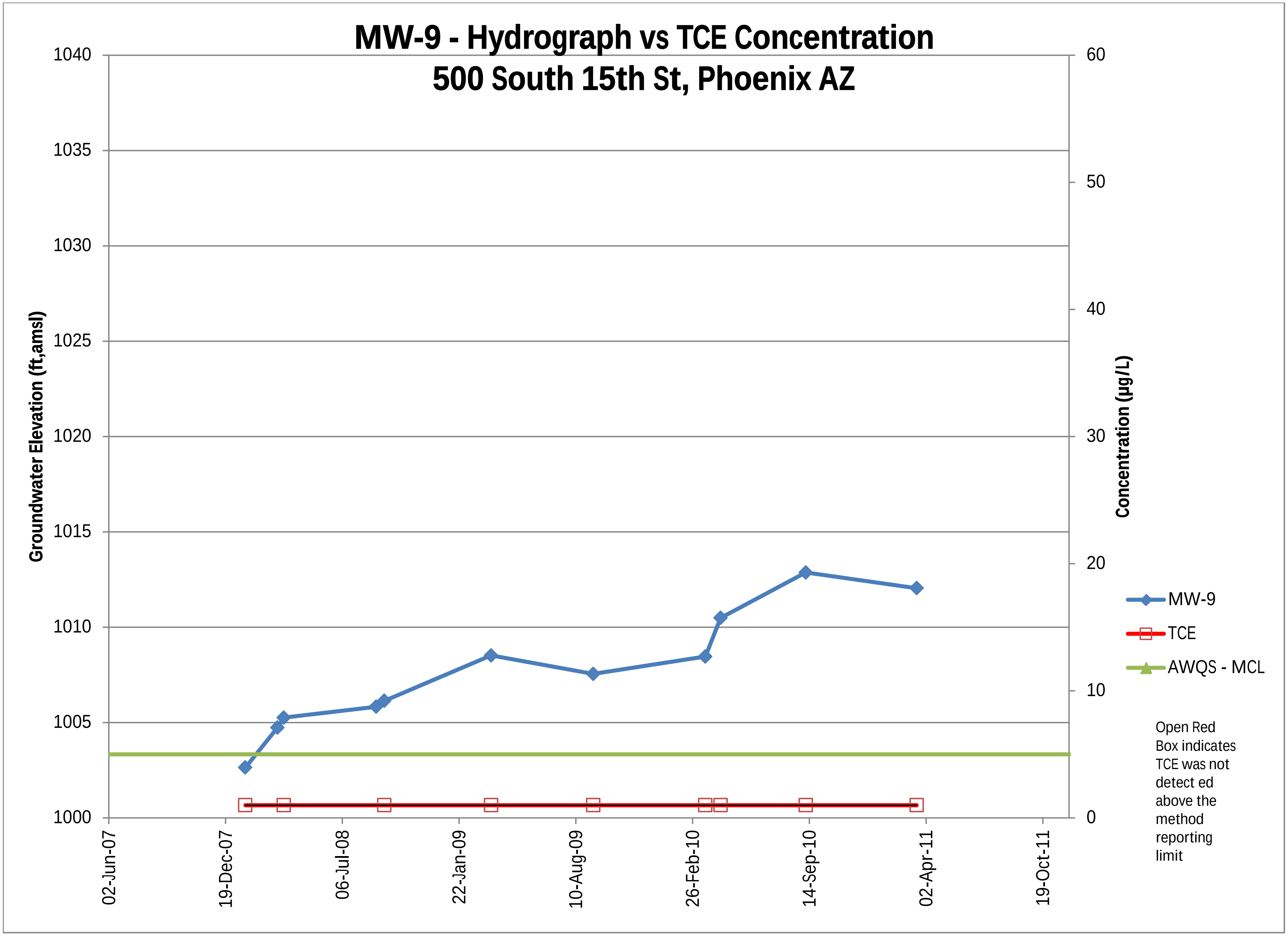


MW-6 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Well was abandoned in August 2005
Groundwater Elevation (ft,amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
08-Dec-91
25-Jun-92
11-Jan-93
30-Jul-93
15-Feb-94
03-Sep-94
22-Mar-95
08-Oct-95
25-Apr-96
11-Nov-96
30-May-97
16-Dec-97
04-Jul-98
20-Jan-99
08-Aug-99
24-Feb-00
11-Sep-00
30-Mar-01
16-Oct-01
04-May-02
20-Nov-02
08-Jun-03
25-Dec-03
12-Jul-04
28-Jan-05
16-Aug-05
04-Mar-06
20-Sep-06
08-Apr-07
25-Oct-07
MW-6
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit



MW-7 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Groundwater Elevation (ft,amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
02-Jun-07
19-Dec-07
06-Jul-08
22-Jan-09
10-Aug-09
26-Feb-10
14-Sep-10
02-Apr-11
19-Oct-11
MW-7
TCE
AWQS - MCL
Open Red Box indicates TCE was not detected above the method reporting limit


MW-8 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Groundwater Elevation (ft,amsl)
1040
1035
1030
1025
1020
1015
1010
1005
1000
Concentration (µg/L)
60
50
40
30
20
10
0
02-Jun-07
19-Dec-07
06-Jul-08
22-Jan-09
10-Aug-09
26-Feb-10
14-Sep-10
02-Apr-11
19-Oct-11
MW-8
TCE
AWQS - MCL
Open Red Box indicates TCE was not detect ed above the method reporting limit



MW-9 - Hydrograph vs TCE Concentration
500 South 15th St, Phoenix AZ
Groundwater Elevation (ft,amsl)
Concentration (µg/L)
1040
1035
1030
1025
1020
1015
1010
1005
1000
60
50
40
30
20
10
0
02-Jun-07
19-Dec-07
06-Jul-08
22-Jan-09
10-Aug-09
26-Feb-10
14-Sep-10
02-Apr-11
19-Oct-11
MW-9
TCE
AWQS - MCL
Open Red Box indicates TCE was not detect ed above the method reporting limit

ARCADIS

Appendix C

Central Phoenix Plume Model, Annual Five-Layer Transient Flow Model Report Text

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICIES

ACRONYM LIST

ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AF	Acre-feet
AF/yr	Acre-feet per year
AMA	Active Management Area
AMSL	Above Mean Sea Level
ARM	Absolute Residual Mean
ASTM	American Society for Testing and Materials
cfs	Cubic feet per second
COP	City of Phoenix
CPM	Central Phoenix Plume Model
ET	Evapotranspiration
FLM	Five-layer, seasonal model
ft	Foot, feet
ft^2	Square foot, square feet
ft^3	Cubic foot, cubic feet
ft/day	Feet per day
ft/year	Feet per year
GHB	General Heads Boundary
gpm	Gallons per minute
GWV	Groundwater Vistas
HBU	Hydrologic Bedrock Unit
K	Hydraulic Conductivity
Kv	Vertical Hydraulic Conductivity
LAU	Lower Alluvial Unit
M52	Motorola 52nd Street Facility
MAU	Middle Alluvial Unit
MAU_1	Upper half of MAU
MAU_2	Lower half of MAU
PCG4	Preconditioned Conjugate Gradient Package (Version 4)
RID	Roosevelt Irrigation District
ROGR	Registry of Grandfathered Rights
SRP	Salt River Project
SRV	Salt River Valley
TEM	Technical Exchange Meeting
TLM	Three-layer, annual model

UAU	Upper Alluvial Unit
UAU_1	Upper half of UAU
UAU_2	Lower half of UAU
USGS	United States Geological Survey
VCONT	Vertical Conductance
VWR	Van Waters and Rogers
WESTON	Roy F. Weston, Inc.
WQARF	Water Quality Assurance Revolving Fund
WWTP	Wastewater Treatment Plant
WVB	West Van Buren

Arizona Department of Environmental Quality
Central Phoenix Groundwater Model
Annual, Five-Layer Transient Flow Model

1.0 INTRODUCTION

This report documents the development of the five-layer, transient, groundwater flow model for the Central Phoenix area. The model area encompasses the West Van Buren (WVB) and former East Washington Water Quality Assurance Revolving Fund (WQARF) project sites from 56th Street on the east to 99th Avenue on the west, and from Camelback Road on the north to Dobbins Road on the south (Figure 1). The final Central Phoenix Plume Model (CPM) simulates groundwater flow for the period 1972 through 1996.

1.1 MODELING OBJECTIVES

The original scope for the CPM project was the creation of a calibrated three-layer transient flow model that could be used to evaluate the stresses on the groundwater system. This flow model would provide the hydrogeologic framework for a contaminant transport model that would be developed after the completion of the CPM.

The development of the CPM proved to be of great interest to the community. To facilitate model development and ensure a uniform flow of information between the modeling team and interested parties within the regulated community, the Arizona Department of Environmental Quality (ADEQ) established a series of Technical Exchange Meetings (TEM) offering a forum for the exchange of technical information and data.

After discussions with participants at the TEM, ADEQ decided to expand the model scope from the three-layer, annual-stress-period flow model (TLM) to a five-layer model (FLM) with seasonal stress periods. The TLM was under development when this decision was made. As a result, the CPM design team continued with the TLM development, although calibration was limited and no sensitivity analysis was conducted. The objective of the TLM became one of facilitating the calibration of the FLM by developing the basic framework of groundwater flow in the Central Phoenix Basin. The TLM was modified by gradually adding more detail, thereby creating the FLM. The resulting CPM is a five-layer, seasonal, transient flow model that can be used to evaluate the long-term effects of existing pumping on groundwater movement within the model boundary. It can also be used to evaluate the effects of proposed remedial alternatives on groundwater flow. In the following report, the acronym CPM refers to the final FLM.

1.2 REPORT STRUCTURE

This report follows the outline defined by the American Society for Testing and Materials (ASTM) for describing a groundwater flow model (ASTM D5718-95). The format has been modified to fit the phased approach used to develop the CPM. The report provides a summary of all phases in the modeling process, but the reader is referred to the original documents for more detailed information.

The document is divided into eight sections. Section 1 provides a summary of the project. Section 2 provides an overview of the physical setting for the CPM. Section 3 discusses the Conceptual Model used as a basis to develop the CPM. Section 4 provides information on the computer program used to simulate groundwater flow. Section 5 begins the specific discussion of CPM construction. Model calibration and the sensitivity analysis are discussed in Section 6. Data gaps identified during the construction of the CPM are discussed in Section 7. Section 8 summarizes the modeling results and provides conclusions as to its applicability for its intended purpose.

1.3 PREVIOUS GROUNDWATER MODELS

Four models have been developed for portions of the CPM area since 1990: the Motorola 52nd Street Facility (M52) model (Motorola, 1995), the Arizona Department of Water Resources (ADWR)/ADEQ Central Phoenix Target model (Corell, 1992), the ADWR Salt River Valley (SRV) model (Corell and Corkhill, 1994), and the WVB group model [Van Waters and Rogers (VWR)] for the WVB area (VWR, 1997). The CPM area is approximately 180 square miles.

The SRV model covers the largest area, 2,240 square miles, with the M52 model covering the smallest area, 20 square miles. The M52 model covered the area from 7th Avenue to 52nd Street and McDowell to Air Lane. The SRV model covered the entire SRV. The VWR model covered 7th Street to 99th Avenue and Camelback to Elliot Rd. Grid spacing ranged from a uniform mile for the SRV model to the variable spacing used in both the VWR [500 to 3400 feet (ft)] and M52 model (200 to 1000 ft).

Each of the four groundwater models was developed with different starting assumptions and different conceptual models for describing groundwater flow within the area. For example, the M52 model assumes that the aquifer east of 24th Street has been under steady-state conditions from 1963 through 1991, while the VWR model assumes that the aquifer west of 7th Avenue is under transient conditions. The simulation periods for each model also varied. The M52 model simulated 1963-1993. The SRV model simulated 1983-1990. The VWR model simulated 1972-1991.

All of the models are three-dimensional (that is, the aquifer is simulated as several hydraulically interconnected layers). The VWR, SRV, and the latest version of the M52 models used MODFLOW, a public domain code developed by the U.S. Geological Survey to simulate groundwater flow.

The SRV model assumes there was recharge from the Salt River to the aquifer. The M52 model did not make this assumption (although flow was permitted across the southern model boundary). The M52 model simulated flow in both the upper alluvial unit and the bedrock; the VWR model simulates flow in the Upper Alluvial Unit (UAU) and Middle Alluvial Unit (MAU), but not the Lower Alluvial Unit (LAU) or the bedrock. The SRV model simulates flow in the UAU, MAU, and LAU. All of the models underwent some calibration (existing data compared to modeled data), but none of the models were validated (an additional period after the end of calibration). The SRV and VWR models did not simulate contaminant transport. The M52 model simulated contaminant transport, as well as groundwater flow.

Other models created for the area include an electric analog model in 1968 (Anderson, 1968), a two-dimensional regional groundwater flow model of the SRV by Long and others (1982), and a model created by the U.S. Army Corps of Engineers for the Rio Salado Project (1998).

Although data were available for all of the models, none of the models completely satisfied the requirements of ADEQ for the CPM.

1.4 STEPS IN CENTRAL PHOENIX MODEL DEVELOPMENT

The creation of the CPM, a transient groundwater flow model for the Central Phoenix area, is the culmination of a project that began with the synthesis of a preliminary Conceptual Model in January 1998 (WESTON, 1998). The Conceptual Model, documented in a letter report to ADEQ, provided a summary of inflows and outflows to the model area. The second step in the modeling effort, a steady-state model, was documented in a letter report to ADEQ in July 1999 (WESTON, 1999a). The steady-state model provided information on the hydrologic system before major pumping stresses occurred. The third step was the development of a three-layer transient flow model to create the framework of the final CPM. This effort was documented in a letter report to ADEQ completed in September 1999 (WESTON, 1999b). The final step in the model development was the modification of the three-layer model to create the five-layer, seasonal model.

1.4.1 Conceptual Model

The Conceptual Model formed the basis for the CPM. It provided the hydrogeologic framework from which the site-specific numerical model was developed and it aided in calibration. The development of the Conceptual Model actually began with an extensive data gathering effort and preparation of a database containing all of the available records for wells, including location and construction information, annual pumping volumes, water levels, water use, river discharge, land use, and recharge in the area (WESTON, 1997). These data were compiled into a water balance summarizing the major inflow and outflow components of the groundwater system for the period 1972-1991. The Conceptual Model was continuously updated as model development proceeded. The updated Conceptual Model is discussed in greater detail in Section 2.

1.4.2 Steady-State Model

The steady-state model was intended to aid in the identification of data gaps and help in developing the transient model by simulating groundwater movement in a period with minimal stresses. The starting water levels for the model came from the 1900 water level map developed by ADWR (Corkhill, et al., 1993) and the 1903 depth-to-water data from W.T. Lee (1905). Calibration goals included a mass balance error of less than one percent and groundwater flow direction and gradients that approximated those shown in ADWR's 1900 map. Calibration target water levels documenting pre-development groundwater levels (Lee, 1905) and a resulting residual mean error were used to improve calibration. The residual is the difference between the measured and model calculated water levels. The residual mean is the sum of the residuals divided by the number of the residuals. The model converged within a reasonable number of iterations and the mass balance error was zero.

During final calibration, aquifer properties and boundary conditions were adjusted within the limits set by available data to approximate the 1900 water table contours. Although the contours generated by the steady-state model follow the pattern in the ADWR's map, they do not overlay the ADWR contours exactly. This is because the CPM steady-state model used newer data on hydraulic conductivity (K), aquifer extent, layer thickness, and water levels in the eastern portion of the CPM area. For example, there were no water level data for the far eastern part of the CPM, but recent work by Motorola at their 52nd Street facility (Motorola, 1995) indicated that water levels in the area are as high as 1195 ft above mean sea level (AMSL) The 1900 water level map set heads in that area at less than 1120 ft AMSL. Recent information and the smaller grid size in the CPM also resulted in changes in UAU bottom elevations and the extent of the MAU. These changes in the CMP also affected the calculated water levels.

In general, the CPM steady-state model reproduced Lee's data, and the direction of flow and hydraulic gradients on the ADWR 1900 water level map. However, unlike ADWR's original assumption that the aquifers were in steady state in 1900, Lee, in his 1903 report, indicates that some areas of the CPM were not in steady-state conditions, and this is verified by the model. Water levels reported by Lee showed both the effects of pumping and drought. Although the model doesn't reproduce the assumed 1900 water levels exactly, it fulfilled its purpose by providing a preliminary evaluation of the revised K and bottom elevation arrays for the UAU and showed that a stable model could be created for the area.

1.4.3 Three-Layer Annual, Transient Model

The TLM, originally intended to be the final product of this project, was completed as the first stage in the development of the transient model. Each of the three major hydrostratigraphic units, UAU, MAU and LAU were treated as model layers. Although the modified goal of the CPM project was to complete a calibrated five-layer seasonal flow model, it was useful to start the transient model development with a simpler model domain, debug the input data and begin the calibration process before moving to the more complex model. This portion of the modeling effort was successful in that problems with the computer program and input data were resolved with less effort than would have been required when the additional complexity of five layers was added.

The TLM calibrated reasonably well and helped define areas in the model where more data are needed such as along the northeastern boundary area where too much drawdown occurred and in the area of the Grand Canal near Indian School where water levels were too high. In addition, the TLM also showed that water levels in the western portion of the CPM are affected by the seasonality of the agricultural pumping. This seasonality, shown in hydrographs of measured water level data, was not reproducible in the TLM because of the annual simulation period. The seasonal water level changes are not as apparent in the eastern portion of the area except during times when the Salt River flows.

The calibration and sensitivity analysis of the TLM was not completed. The TLM was documented in a report to ADEQ in 1999 (WESTON, 1999b).

1.4.4 Five-Layer, Seasonal, Transient model

The FLM is the final product for this modeling effort. It is calibrated and a sensitivity analysis was completed. The FLM was constructed from the framework already established in the TLM. The model area, grid dimensions, and the definition and location of boundary conditions remain the same as in the TLM, but the hydrogeologic framework is modified. The UAU and MAU were each split into two layers. The aquifer parameters, which in the TLM were an average for the entire thickness of the layer, were modified to reflect the change in the layer thickness and aquifer materials. The transient data arrays were converted from annual rates to seasonal rates. In addition, the external heads used for the general head boundaries were converted from a steady-state condition (one head used at a node for the 25 years) to transient conditions (the head at a node varied with time). The FLM is also run for 25 years (from 1972 through 1996), but instead of 25 annual stress periods, there are three stress periods of unequal length per year for a total of 75 stress periods. The conversion of the TLM to the FLM is discussed in greater detail in the remaining sections of this report.

In 1997, when Roy F. Weston, Inc. (WESTON) developed the database used in the CPM, there were more than 500 wells within the CPM area. Each of these wells had several identifiers: an ADWR Registration Number (55-number), a cadastral location, and an identifier given the well by its owner or installer. Although the 55-number is unique, it is not commonly used by the public. Neither the cadastral nor the owner name is unique, since several monitor wells may be located in one 10-acre parcel. The CPM project needed a method to uniquely identify each well as succinctly as possible. The decision was made to assign each well a three-letter facility or owner designator and then a number. Appendix A provides the correlation for cadastral, 55-number, and CPM number for wells within the CPM area.

2.0 STUDY LOCATION

2.1 GENERAL SETTING

The CPM covers approximately 180 square miles encompassing residential, commercial and agricultural areas north of South Mountain and roughly centered on metropolitan Phoenix. The CPM area is adjacent to the cities of Tempe, Scottsdale, Glendale and Tolleson, bounded by 56th Street on the east, Camelback Road on the north, Dobbins (Guadalupe) Road on the south, and 99th Avenue on the west (Figure 1). This area encompasses both the WVB and former East Washington WQARF Project areas.

The Phoenix metropolitan area is experiencing rapid growth. The population in the Phoenix metroplex has reached more than two million residents (ADWR, 1991) and these increases have affected the entire SRV including the CPM area. The direct impact of this growth is a decrease in the acreage devoted to irrigated agriculture and an increase in commercial, residential and industrial use beginning in the 1970s. As a result, although urban water demands are close to those of agriculture, the aquifer recharge from excess agricultural applications ceases. Excess urban effluent is channeled to treatment plants and becomes riparian recharge along the Salt River Channel. These changes in recharge type and location change the dynamics of the groundwater system.

2.2 CLIMATE

Hot summers and cool winters characterize the SRV, located within the Sonoran Desert Climatic Region of Arizona. Average maximum temperatures reach a high of 105° F in July and a low of 65° F in January. Minimum temperatures range from an average of 80° F in July to an average of 39° F in January (ADWR, 1991).

Annual precipitation averages 7.2 inches across the valley with the majority occurring during the summer months of July through September and the winter months of December through

March. Little precipitation occurs during the spring and fall. Average annual evaporation is approximately 72 inches, with the greatest evaporation occurring during the hot summer months (Corkhill, et al, 1993).

2.3 TOPOGRAPHY

Topography in the project area is characterized by a broad, flat-lying alluvial plain cut by low stream terraces and floodplains located in and adjacent to the Salt River and other unnamed washes. Alluvial fans have formed adjacent to Camelback Mountain and Barnes Butte, the topographic highs within the area. Elevations range from l,015 ft AMSL near the Salt River to 1,240 ft AMSL in the northeast portion of the project area. South Mountain forms the southeastern boundary of the CPM. Landsurface elevations gradually decrease to the west where the Salt River merges with the larger Gila River system (Figure 2).

2.4 LAND USE

Land use in the CPM area was mapped using aerial photographs for 1976, 1988, and 1995, (Figures 3, 4, and 5). Predominant land uses within the project area are urban residential, office complexes, strip malls, and light industrial on the east; and agricultural mixed with light industrial in the west. Industries in the eastern portion of the area include those associated with aircraft testing and components manufacturing, automobile rental facilities, dry cleaning, and electronic component manufacturing. Industries in the western portion include bulk fuel terminals, a former aluminum plant, warehouses, chemical companies, and light manufacturing. Municipal facilities include Sky Harbor Airport, several landfills and various maintenance and storage facilities associated with the City of Phoenix (COP) and the Salt River Project (SRP).

2.5 GEOLOGY

The area addressed in the CPM is entirely contained within the West SRV. This alluvial basin, defined by block faulted mountain ranges along its borders, is characteristic of Basin and Range physiography. The rocks that form the bounding mountain ranges and floor the valley are predominantly Precambrian crystalline rocks forming nearly impermeable boundaries to groundwater flow and are collectively referred to as the Hydrologic Bedrock Unit (HBU).

2.5.1 Central Phoenix Lithology

The alluvial basin of the SRV consists of thick basin-fill deposits of unconsolidated to semi-consolidated Late Tertiary to Quaternary sediments that overlay the HBU. They range in thickness from zero feet near the basin margins to several thousand feet along the axis of the basin and consist of interbedded sequences of cobble, gravel, sand, silt, clay and evaporites. The lithologic relationships observed in local wells are interpreted as representing alluvial fan and playa deposits formed in a closed basin during the early and middle stages of basin development, followed by fluvial and alluvial fan deposits formed during the late stages of basin development after the establishment of through-flowing drainages (Corkhill, et al, 1993). These deposits are subdivided into three hydrogeologic units that comprise the regional aquifer in the SRV and are the primary focus of the modeling effort:

1) LAU
2) MAU
3) UAU

These are discussed in the following sections that are summarized from Corkhill, et al, 1993. The three major units are shown on geologic cross sections, Figures 6 and 6A through 6E.

Lower Alluvial Unit

The LAU overlies, or is in fault contact with, the HBU. The LAU consists mainly of conglomerate within the CPM area and locally contains intruded volcanic rocks. Sediment within the unit was derived from the surrounding mountains. Although absent near the basin margins, the LAU reaches thicknesses of several thousand feet in the central basin.

The LAU was deposited during the early stages of development of the alluvial basins. The increasing thickness and decreasing particle size of the LAU with increasing distance from the mountain fronts suggest that the alluvial basins were closed during deposition of the unit. (Laney and Hahn, 1986)

Middle Alluvial Unit

The MAU overlies the LAU, and within the CPM area, the MAU consists predominantly of silt and clay with interbedded sand and gravel lenses derived from surrounding mountains. Although seemingly minor in thickness when compared to the clay units, the sand and gravel levels can yield large quantities of water to wells. Near the basin margins, the MAU consists mainly of sand and gravel and is difficult or impossible to distinguish from the other units.

The unit is absent east of 24th Street in the eastern valley area yet reaches thicknesses of 1,600 ft in the deeper western portions of the basin. K estimates for the MAU range from about 5 to 50 ft/day, based on aquifer test results and specific capacity data

Upper Alluvial Unit

The UAU extends from land surface to the top of the MAU. The UAU consists mainly of silt, sand, and gravel deposited during the final stages of development of the alluvial basin. The relatively uniform thickness of the unit and association of coarser-grained sediments with the locations of major drainages suggest that the unit was deposited by the ancestral Salt River after the establishment of through-flowing drainages, and from alluvial fans along the mountain fronts.

The total thickness of the UAU is relatively uniform and does not show the same trends characteristic of the MAU and LAU. As shown in figures 6A through 6E, the UAU is typically between 200 and 500 ft thick in the CPM area.

2.6 GENERAL HYDROLOGIC SYSTEM

Groundwater flow regimes in the CPM area are dominated by regional pumping centers with recharge supplied from excess agricultural irrigation, canal leakage, and occasional flood events.

Groundwater movement within the region is predominantly controlled by the areal distribution of recharge and pumping. Several geologic features exert control over the direction of groundwater movement on a local scale. These include the location and distribution of non-waterbearing formations, locally discontinuous and regionally extensive fine-grained or consolidated deposits, the "bedrock highs" in the eastern and the north central part of the model, and the presence of fault systems in the basal portion of the LAU.

One of the earliest documents dealing with aquifer conditions in the Phoenix area was authored in 1905, by W.T. Lee, a geologist with the United States Geological Survey (USGS) (Lee, 1905). According to Lee, groundwater development in the Central Phoenix Basin began in the late 1800s as agriculture expanded and erratic flows in the Salt River could not meet the increased demand with any regularity. Early wells were predominantly large, hand-dug holes designed to reach a water table that was usually within 30 ft of the land surface. Lee recognized that groundwater development would increase in the valley and that some attempt should be made to document predevelopment conditions. The resulting report provides a detailed look at historic conditions and formed the basis for the steady-state model discussed later in this report.

Subsequent to Lee's work, numerous authors tackled the task of documenting aquifer conditions over time in the SRV groundwater system. These were reviewed in the course of compiling the CPM. Those that proved most useful were the SRV modeling reports by various authors published under the auspices of the ADWR. Because of the extensive data gathering capabilities of this state agency, ADWR had already compiled pumpage and recharge data, canal flow information and data on aquifer characteristics.

In addition to reports published by the state and federal agencies, numerous documents authored by private consultants within the CPM area were on file at the ADEQ or were made available to WESTON through separate arrangement. Reports by Dames and Moore for the M52 provided valuable insight into the geologic and hydrologic conditions in the east valley. A numerical model of the west SRV, dubbed the VWR Model, helped with the definition of aquifer characteristics and the compilation of historic pumpage on a seasonal basis for the area west of 7th Street.

Additional data were gathered from various theses on file at Arizona's universities. A report by Phillip Hutton (1983) provided insight into the flow characteristics of the local aquifer. A thesis by Eric Zugay (1995) provided valuable information on the availability of recharge from Salt River storm flows within the CPM area. Additional data on recharge from Salt River flood events were obtained from professional papers and reports by Briggs and Werho (1969), Bales, Schulten and Pewe (1980), Mann and Rohne (1983), and Turner (1983).

The hydrogeologic setting of the SRV was described in detail by the ADWR in a series of reports dealing with development of the SRV Model. These documents collated work done by Laney and Hahn (1986) on the hydrogeology of the eastern part of the SRV and Brown and Pool (1989) on the hydrogeology of the western part of the SRV. The hydrogeologic interpretation presented herein is taken predominantly from the ADWR report with modifications based upon more recent investigations.

3.0 CONCEPTUAL MODEL

The Conceptual Model identifies and summarizes the major flow components of the aquifer system and provides the description of the aquifer parameters. For the CPM, the major flow components included:

- outflow, in the form of pumping and groundwater movement out of the model area along the western boundary;
- inflow from canals, deep percolation from irrigated agricultural fields, and Salt River recharge coupled with groundwater movement into the model across the boundaries; and,
- the changes in storage that result in any dynamic system.

3.1 TIME PERIOD SELECTION

The conceptual model and water budget must be defined for a specified time period. Selecting a time period requires consideration of stresses on the system and the timing of the stresses. For example, a flow model usually is begun when an aquifer is under steady-state conditions. This means there are no changes in storage in the model with time. Starting in steady state insures that the water levels calculated by the model are a result of current conditions and not some past action, thereby simplifying model calibration. If a model begins under transient conditions, water level changes at a specific time period are an integration of those stresses on the system that have occurred to date.

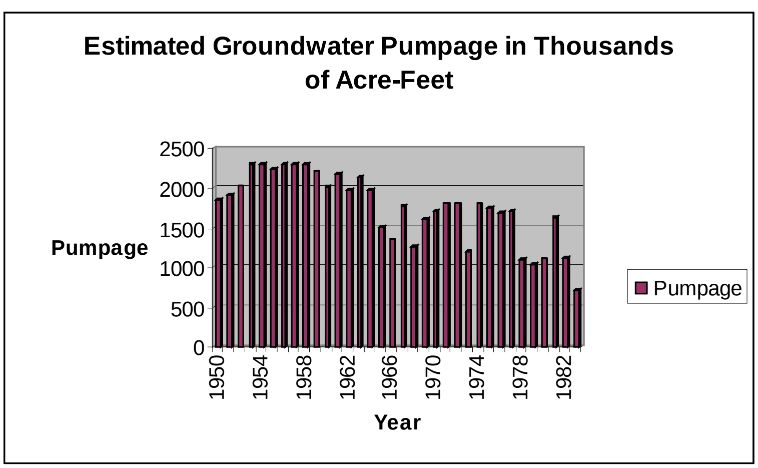
It would be simplest if the CPM could begin under steady-state conditions. However, as discussed in Section 2.5, the aquifer was in transient conditions as early as 1903. That is, the stresses on the system such as pumping and recharge were changing with time. These changes impact water levels as well as outflows from the model area. Therefore, beginning the CPM in a time when the aquifer was in steady-state conditions requires starting the model simulations prior to 1903.

The difficulty with the pre-1900 start date is that there are limited data. Few water level measurements exist for the CPM area prior to the 1970s. Much of the data for the year period between 1900 and 1970, such as pumping volumes and well locations, are estimates. Some of the regional models with grids encompassing a square mile did begin simulations in the early 1900s (Long et al, 1983; Anderson, 1968), but data were lumped within square mile areas. The CPM team believed the level of uncertainty inherent in these data did not merit the effort required to assemble and distribute the data for the smaller CPM grid spacing. Therefore, the decision was made to begin the CPM in transient conditions.

Having made the decision to begin the CPM simulations under transient conditions, the next step was to determine when to begin the model. The ultimate purpose of the model, coupled with a review of estimated pumping volumes for the CPM area and the availability of water level data helped determine the beginning time period for the model.

The CPM's purpose is to evaluate proposed remedial alternatives. Therefore, the time period of most interest to ADEQ is the 1990s and later.

The volume of water pumped within the CPM area has changed with time. Prior to 1982, pumping was estimated by various agencies. After 1982, the water right holder reported pumping to ADWR. The estimated volume of water pumped in the whole SRV from 1950 through 1983 (Reeter and Remick, 1986) is shown below. This graph is for the entire SRV, an area of approximately 2,240 square miles.



The graph shows that pumping volumes remained relatively constant in the 2,000,000 acre-feet/year (AF/yr) range, until 1964. By 1965 annual-pumping volumes decreased and from 1965 through 1978 the pumping stayed between 1,300,000 and 1,800,000 AF/yr. After 1978 the pumping stayed around 1,000,000 AF/yr. Within each of the three periods, aquifer responses to pumping would remain similar (assuming that other stresses such as recharge remain similar for the same period). By starting the CPM at the middle or end of a period with similar pumping volumes, the transient affects could be minimized.

Review of agency files for water level data within the CPM area showed an areawide effort by the USGS to measure water levels in the SRV in 1972, 1982, and 1991 (Bureau of Reclamation, 1976; Reeter and Remick, 1986; ADWR, 1993). As expected, there were fewer data for 1972 and more data for 1991.

Based on the model purpose, the pumping distribution, and the water level data, the beginning time for the CPM was picked as 1972. This starting date provides an 18-year period during which the effects derived from starting the model under transient conditions are ameliorated and provides sufficient time prior to 1990 to examine the changes in the aquifer resulting from pumping. WESTON selected a starting date of January 1, 1972. The ending date for the model was set for the year 1995. This was the latest year for which complete pumping data were available when the project began. Although 1996 was modeled, pumping data were only available for the first half of the year.

3.2 DATA SOURCES

Once the start date for the CPM was selected, a conceptual model and water budget were developed for the period 1972 through 1995. The data necessary to quantify individual components of the conceptual model were assembled from various sources including, but not limited to, government agencies, private utilities and university publications.

The primary data sources included:

1) **Registry of Grandfathered Rights (ROGR) Data Base:** ADWR, Phoenix Active Management Area (AMA) maintains the ROGR Database. All water use within the AMA is reported to this agency each year. Records date from 1982 and can be tracked retroactively to 1975 with some accuracy.
2) **ADEQ project files:** The project files at ADEQ proved an invaluable source of background data for completing the CPM. Reports submitted to ADEQ included detailed lithologic logs of monitor wells, monitor well aquifer test results and historic water level information.
3) **ADWR:** The records from the ADWR Records Section provided well location and construction data, while the Hydrology Section took an active interest in the project and allowed WESTON unrestricted access to all of the files used in compilation of the SRV Model as well as data submitted as part of various Assured Water Supply Studies and General Industrial Use Permits. Reports available in the Hydrology Section also provided Salt River flow data for the period being modeled.
4) **Roosevelt Irrigation District (RID):** RID provided not only annual and monthly pumping records for all of their wells, but effluent diversions from the COP 23rd Avenue Wastewater Treatment Plant (WWTP) as well.
5) **SRP:** SRP provided annual pumpage records for all of their wells along with canal flow and construction data.
6) **Cities of Phoenix and Tolleson:** The cities of Phoenix and Tolleson provided historic pumping, water level, and aquifer test data.

3.3 HYDROSTRATIGRAPHY

The entire SRV lithologic sequence is represented within the CPM area. The UAU is present throughout the area and is the unit in which the majority of wells are completed. In general, it consists of loosely consolidated sands, gravels, and clays grading from coarser materials near the eastern margins of the study area to finer material in more central locations. The MAU is absent in the eastern basin area yet reaches thicknesses of 1,600 ft along the western boundary.

The LAU is also absent in the eastern part of the area. Figures 6 and 6A through 6E show the general hydrostratigraphy of the CPM area.

Characterization of the basin fill deposits has been discussed in numerous documents ranging from map series to reports published under the auspices of the U.S. Geological Survey, the U.S. Bureau of Reclamation, and Arizona Bureau of Mines, etc. The following paragraphs provide a synopsis of this past work and are intended to establish a basic understanding of primary lithologic units present in the CPM area and their influence on groundwater movement and yields to wells .

The Basin and Range Physiography was formed as a result of high-angle block faulting between 15 and 8 million years ago (Brown and Pool, 1989). The lower part of the basin fill (LAU) overlies a redbed sequence that predates faulting. The LAU is predominantly a conglomerate intermixed with finer-grained lenses and has been estimated to reach thicknesses in excess of 10,000 ft in the central portions of the valley (Brown and Pool, 1989). The LAU yields little water to local wells and was considered to contribute only marginal amounts of water to the overlying systems in the CPM area. Because of its depth and low yield, few wells have penetrated the LAU.

By contrast, although predominantly comprised of finer grained silts, clays and silty sands, the MAU contains enough sand and gravel deposits to yield significant quantities of water to wells and is considered a major aquifer. Many of the finer-grained deposits in the MAU can be associated with ancient playa environments due to the extensive evaporite deposits encountered (Brown and Pool, 1989). As more through-flowing streams developed, the lithologic sequence grades into fluvial sands and gravels interspersed with clays most commonly associated with backwater areas. More rounded sands and graded gravels found in modern alluvial fans can also be found distributed along the margins of the valley in the MAU. Within the CPM area, the MAU is defined by thick clay sequences characterized by drillers as *hard brown clay* or *sticky red/brown clay* depending upon location.

The upper unit of the basin fill (UAU) is comprised of gravel, sand, and silt with small amounts of clay, usually in a sand matrix. Within the CPM area, the unit is unconsolidated and grades from predominantly gravel and cobbles near the Salt River to finer floodplain deposits in adjacent areas (Brown and Pool, 1989). The UAU is the most productive unit of the three and most water production wells in the CPM area extract a large portion of their water from this source.

3.3.1 Division of UAU and MAU

The UAU is loosely consolidated silts, sands, and gravels. Clays are present but only in minor amounts. For the purposes of the CPM, the transition between the UAU and MAU was considered to be that area within the lithologic sequence characterized by at least 40 ft of material, often referred to as *hard brown clay* or s*ticky brown clay*. Below this point, the lithology usually shows a marked increase in the amount of fine-grained material present. The driller's logs utilized in this analysis were selected on the basis of depth, detail, and location. Although there are numerous logs associated with ongoing environmental investigations in the area, most are for shallow wells that, in many cases, penetrate only the uppermost sequences of the upper alluvial unit.

3.3.2 Subdivision of UAU

Initially, the CPM was divided into the three major units: the UAU, MAU and LAU. Upon further consideration, it was decided that the model objective of simulating groundwater movement in the CPM area would best be served if these units were further subdivided to reflect more subtle changes in lithology.

Although the lithology of the UAU is distinctive in most areas of the basin, enough gradation exists within the unit to allow separation into two sublayers. The uppermost layer is comprised of loose surface soils, grading downward into interfingered sand and gravel lenses. Clay lenses, when present, are thin and usually characterized as *clayey sands*. Although the lower portions of this layer are saturated throughout the CPM area, the layer may dewater in the areas nearest pumping wells. Termed UAU_1 for purposes of identification, the breakpoint between this and the lower UAU (termed UAU_2) is the point where clay lenses within the unit increase in number until clays dominate the lithologic horizons.

Driller's logs for wells A(1-1)14bab, A(1-3)26ccc, and D(1-2)6add are attached for reference and to demonstrate the selection process utilized (Figures 7, 8, and 9). The locations of these wells can be found on Figure 6.

3.3.3 Subdivision of the MAU

Although numerous wells penetrated the UAU in the CPM area fewer than ten wells penetrate the entire thickness of the MAU and also have driller's logs. All of these are located in the far western portion of the model area. As a result, a definitive marker horizon could not be established; and, it was not possible to subdivide the MAU using a technique similar to that employed with the UAU. Instead, the MAU was simply divided in half with the top half designated MAU_1 and the lower half MAU_2.

3.4 AQUIFER SYSTEM

The aquifer system consists of the hydrostratigraphy defined in the previous section plus the groundwater flow. The three major units defined above, the UAU, MAU and LAU all contain measurable quantities of water. However, this water is stored and moves under different regimes for the UAU and the two deeper layers. Water in the UAU is considered unconfined. That is, the point at which water is encountered in a well in the UAU is equal to the level of the water table because the water is at atmospheric pressure. It is assumed that the MAU and LAU are both confined systems. A confined system is located beneath a layer of less permeable material that acts as a barrier to vertical flow. Water pressure in a confined aquifer is higher than atmospheric and water levels in a well will be higher than the bottom of the confining unit.

It is apparent from pumping data and water responses in wells that all three units are hydraulically interconnected. Whether water in the MAU and LAU is always confined throughout the CPM area is not clear because of the heterogeneous nature of the sediments and the limited data.

3.4.1 Water Levels

There are three years with basinwide water level data collected over a short time period, 1972 (Figure 10), 1982 (Figure 11), and 1991 (Figure 12) (Bureau of Reclamation, 1976; Reeter and Remick, 1986; ADWR, 1993). The data for the 1983 and 1991 maps were collected in December, January, and February when the agency assumed pumping was minimal. However, both the 1983 and 1991 maps have posted data on the original maps that obviously were not used when the data were contoured. These data indicate that some of the wells in the area were still pumping when the water levels were measured. This provides a dilemma when determining inflow and outflow across the area boundaries. When pumping is active in the area, a groundwater divide is created near the northern CPM boundaries. During non-pumping times, flow occurs to the west and southwest. Based on pumping records, WESTON assumed that pumping is the more normal condition within the western CPM area. The water-level maps are used for a general comparison of direction of flow, contour shapes, and hydraulic gradients.

In addition to the ADWR's basinwide water-level collection program every ten years, (1972, 1982, and 1991) ADEQ has measured water levels on a semi-annual basis across the CPM area during the 1990s. All of the water-level data available prior to and including 1996 were used in the CPM and are listed in Appendix B. Additional investigations at facilities in the 1990s yielded data collected as frequently as weekly. Unfortunately, many of the wells were not surveyed for Arizona state plane horizontal coordinates and elevations. In addition, many of the wells are completed across multiple hydrologic layers yielding a composite water level rather than a depth-specific measurement.

The water table contour maps were compiled from initial data sets, which included water level measurements collected by ADWR for the target years 1972, 1982, and 1991. These data were augmented with measurements from other sources such as the SRP, RID, and the cities of Phoenix and Tolleson. In all cases, the measurements were selected because both the well and measurement date could be verified. For each time period, the data were plotted on a base map and a preliminary contour map created. These preliminary runs served two purposes. First, they highlighted areas where data were too sparce to allow adequate contour delineation.

Second, water levels that seemed inconsistent with those around them, i.e., too high or too low, could be rapidly identified.

To fill in gaps in the spatial distribution of water levels, WESTON turned to the published U.S. Geological Survey and Bureau of Reclamation water level maps for the specified time periods. Although specific data points are posted on these maps, the well is not identified by a location number. For this reason, although these data were assumed to be valid and were transferred to the CPM water level maps, they were given a different well symbol to indicate that the exact well location was unknown.

In the case of inconsistent water levels, individual well records were pulled to compare perforated intervals and lithology between neighboring wells and pumping records to see if the observed water level was a flash static. Depending upon the results of this assessment, individual water level measurements were discarded as unrepresentative of the system.

Figure 10 shows the 1972 water-level map, the starting water level data for the CPM. Water levels in each layer of the CPM are set to the heads shown in this figure. The original water level contours are from the map developed by the Bureau of Reclamation for the Central Arizona Project report (Bureau of Reclamation, 1976). At the time the 1972 map was developed, there were limited water level data in the eastern and southern portions of the CPM area. Work done for facilities in the eastern area in the 1990s showed that water levels were as much as 60 ft higher than those assumed by the Bureau of Reclamation. There is minimal pumping in the eastern area, so the 1972 water-level map was modified to reflect the higher 1990 water levels in this area. There were limited data for the area south of the Salt River and there is still little data available in this area.

Another area where there is a discrepancy between extrapolated contours for 1972 and more recent site-specific data is in the area of the F&B Facility north of Indian School Road. Recent data indicate that a local bedrock high distorts the water level contours in that area (Zimmerman, 1999). The 1972 map does not reflect the more recent data in this area.

Groundwater movement within the region is controlled by several geologic features: the location and distribution of non-waterbearing formations, locally discontinuous and regionally extensive fine-grained or consolidated deposits, the “bedrock high” in the eastern part of the model east of 24th Street, and in the north-central area of the model between Thomas and Indian School roads west of Interstate Highway 17. These shallow bedrock areas appear to support the presence of fault systems in the basal portion of the LAU.

Regional directions of groundwater movement throughout the CPM area are dependent upon pumping and seasonal weather conditions. In the eastern portion of the model, groundwater has a southerly and southwestward flow component. The Salt River is the main channel for surface runoff and a source of recharge to the groundwater. However, it is normally dry. When releases are made from upstream impoundments and the Salt River flows, the hydraulic gradient adjacent to the river fluctuates measurably. When agricultural irrigation wells (i.e. the RID and SRP wells) are pumping at high rates, groundwater flow directions are impacted. As a result, groundwater gradients and flow directions vary throughout the year throughout the CPM area. Groundwater recharge to the basin aquifers is derived from infiltration of precipitation, infiltration of runoff from the adjacent mountains, infiltration of controlled releases from upstream reservoirs along the Salt River, return flow from agricultural irrigation, canal seepage, and subsurface groundwater inflow from adjacent areas. Although the groundwater basins in the Phoenix region are considered to be in overdraft condition (ADWR, 1991), groundwater elevations have increased locally by as much as 50 to 70 ft since the mid-1960s as shown in the water table contour maps. The water level increase is due to overall decreases in groundwater use and from higher than normal precipitation.

Under non-pumping conditions, the direction of groundwater movement is primarily in a westerly direction, roughly parallel to the Salt River drainage. Recharge from infiltration of flood flows along the Salt River does not significantly change the flow directions regionally but may cause local increases in groundwater elevations immediately adjacent to the channel (Turner, 1983).

Historic groundwater level data from 1930 to 1965 indicate a general decline of groundwater elevations of up to 130 ft in the northwest section of the area (Reeter and Remick, 1986). Over the same period, groundwater elevations near the Salt River were subject to declines of 25 to 50 ft. Post-1965 groundwater elevation data indicate a general rise in groundwater elevations up to 20-80 ft in the northern portion of the area (Reeter and Remick, 1986). The depth-to-groundwater within the CPM area ranges from approximately 40 ft along the Salt River at the southern boundary to nearly 100 ft in the western portion of the area.

In the eastern part of the project area, the hydraulic gradients average approximately 18 to 25 ft per mile toward the west and southwest (Kleinfelder, 1989). Hydraulic gradients average from 7 to 10 ft per mile to the west in the northwestern portion of the CPM area.

3.4.2 Vertical Gradients

There are several locations within the CPM area where nested piezometers in wells, which limited screened intervals, have been installed. These include wells at the Dolphin Facility as well as several ADEQ installed wells. In general, the wells completed in the UAU have higher water level elevations than those in the MAU indicating downward flow. This situation varies depending upon time of year and pumping in the area.

3.4.3 Hydrologic Boundaries

Figures 13 through 17 show the extent of each of the five layers used in the model. The creation of a groundwater flow model is simplified if the model boundaries can be set to physical features that control flow such as an impermeable mountain range. Although the SRV is bounded by units that are considered to be hydrologically impermeable when compared with the more permeable alluvial valley fill, the CPM area is a subset of the SRV and its edges do not coincide with these hydrogeologic boundaries. As a result, the model boundaries have to be described by an artificial mechanism that simulates flow across the boundary with time. The boundary conditions parallel the local hydrogeologic system as reflected in the water table contour maps. There are three types of flow conditions along the model boundaries within the CPM that need to be defined:

- areas with time variant flow and heads
- areas with constant flow and head
- areas with no-flow across the model boundaries

These areas are shown in Figures 13 through 17.

Areas with time variant-flow and heads occur where no hydrologic barriers exist so groundwater can flow into or out of the model area in response to changes in stresses. This condition exists along the northwestern, western and southwestern model boundaries. Flow across these boundaries is transient, changing with time and location.

The eastern, northeastern and south-central areas of the CPM have the second type of flow conditions, constant flow. Although the eastern CPM area abuts the impermeable units of Papago Buttes, there is inflow to the aquifer from surface recharge and additional inflow available to the system from adjacent areas and from the infiltration from canals, irrigation and leaky pipes.

The final type of flow condition is seen along the remaining one-third of the southern boundary, adjacent to South Mountain. This area of the CPM is considered an impermeable boundary resulting in no flow into or out of the model area.

3.4.4 Hydraulic Properties

The hydraulic properties to be defined for the CPM area include K, specific yield/storage coefficient, extent of each of the hydrostratigraphic layers, and the thickness of each layer.

3.4.4.1 Hydraulic Conductivity

The information on K is limited within the CPM area. Data generally fall into three categories: aquifer tests performed for various facilities in small diameter monitor wells, tests performed in production wells, and specific capacity data. Results for the facility tests are for a site-specific area and for a discrete zone within the aquifer. The other aquifer test results are available from a variety of sources including the ADWR and USGS (Hutton, 1983), but tend to be for large diameter production wells that are screened across multiple aquifer units. Results for both types of tests have limitations when applied to the CPM. The facility tests yield localized data. The production well tests provide average data for several units. Figure 18 shows the location of the aquifer tests and the calculated transmissivities.

The raw data for many of these tests are not in agency files or facility reports so the methods used in calculation and the test specific information are not available. This presents a problem because the CPM requires K, not transmissivity. Therefore, the transmissivities reported in the literature were converted to K's by dividing the transmissivity by the saturated thickness penetrated by the well, and preferably, the well screen.

The effects of partial penetration were not considered to be an issue given the scale of the model. During subsequent model development, the initial conductivity values were modified to some small degree. Each time this occurred, the basic data were reexamined to ensure that the change was justified. In most cases, these changes required an increase in K values. The justification in these cases was that the K's were developed using the entire thickness of aquifer penetrated or screened including thick clay lenses. As a result, the calculated K was probably substantially lower than the "effective" K.

The third type of aquifer data, specific capacities, was available for some production wells. The specific capacities, which were mainly available for RID, SRP, and COP wells, were converted to an approximate transmissivity using the technique described by Anderson in 1968. For older wells in Arizona's alluvial valleys, transmissivity is equal to the specific capacity of the well multiplied by 2000 (Anderson, 1968). Specific capacity is pumping rate divided by drawdown in the well. This method provides an order of magnitude value that can be compared with other data. In the final analysis, these conductivities were used only for comparison with aquifer test results.

Once the transmissivity values were converted to K's, the calculated conductivities were plotted on the CPM base map and zones of apparently equal (order of magnitude) aquifer properties were developed. The K in the UAU ranges from 5 to 700 ft/day; the range for the MAU is 7 to 30 ft/day; the range for the LAU is 3 to 20 ft/day.

There were insufficient data to calculate vertical hydraulic conductivities (Kv) values for the CPM area. As a result, Kv's were set at 10 percent of the horizontal conductivity, a common convention.

3.4.4.2 Storage Coefficient/Specific Yield Arrays

For the UAU, the specific yield values are taken directly from the ADWR SRV model (Corell and Corkhill, 1994). Originally, the storage coefficients for the MAU and LAU were also set to the ADWR's values. However, ADWR set the primary storage coefficient equal to a uniform 0.005 for all of the layers. After TEM discussions, WESTON elected to set the primary storage coefficient equal to an order of magnitude lower than the specific yield used by ADWR. The specific yield ranges from 0.08 to 0.20 in the shallow UAU_1. The deeper UAU_2 storage coefficients/specific yields range from 0.009 to 0.02. The MAU storage coefficients range from 0.0003 to 0.0005. The LAU storage coefficients range from 0.001 to 0.0009.

3.4.4.3 Bottom Elevations

The decision was made to subdivide the UAU and MAU and to consider a portion of the total LAU thickness in the CPM; therefore, the bottom elevations of each of the five layers had to be defined. Figures 19 through 23 show the bottom elevations for the five layers.

The bottom elevation contour maps for the UAU_1 and UAU_2 were developed using drillers' lithologic logs collected as part of the Phase I Database (WESTON, 1997). For the purposes of this analysis, the bottom of the UAU was assumed to be located at the point where the driller encountered a significant thickness (20 ft or more) of *sticky brown clay* or *hard clay*. It should be noted that although the bottom of the UAU is referred to as a continuous surface, it is actually a discontinuous sequence of individual lenses. When taken together, these comprise a lithologic horizon marking a gradual change in sedimentary character from the sands and gravels of the UAU to the clays and finer- grained facies of the MAU. Geophysical logs were available for numerous shallow wells and a few deep wells throughout the area. These logs were examined and, although most were too shallow, deeper logs were found to correspond with the drillers' calls.

Once the depths had been extracted from the geophysical and lithologic logs and geological reports, the elevations of the marker horizons were determined by referencing area USGS topographic maps. UAU Bottom elevations within the CPM area range from 1180 ft AMSL in the eastern model area to less than 500 ft AMSL along the western model area. The UAU bottom elevations were modified for the bedrock highs identified during the 1990s in the eastern portion of the model (Motorola, 1995) and in the area of the F&B Facility (Zimmerman, 1999).

These elevations and well locations (in state plane coordinates) became an XYZ file in SURFER. SURFER's kriging package was used to contour the random data.

The first contour map of the bottom of the UAU showed good spatial correlation between data points regardless of source with approximately ten percent lying outside the trend in any given area. The lithologic logs of these outliers were reexamined to determine first if the locations of the marker horizon were accurate and, second, if the log itself appeared to accurately depict local lithology. In most cases, the zone picked on the first pass marginally fit the selection criteria or the data were sketchy requiring a judgment call on the part of the observer. Once these points were removed or adjusted, the UAU bottom elevations more closely depicted a continuous surface.

The MAU and LAU bottom elevation data were taken directly from the SRV model. These original contour maps were modified during the development of the CPM using additional information on completion depths of pumping wells in the area. In addition, pumping wells were identified along the eastern edges of all three layers in areas that had been originally defined as inactive in the steady-state model. The layers were extended toward the east to accommodate these wells. All of the additional areas were within the zone originally assumed by WESTON to be potentially within the active model area. Figures 19 through 23 show the bottom elevations for the five layers.

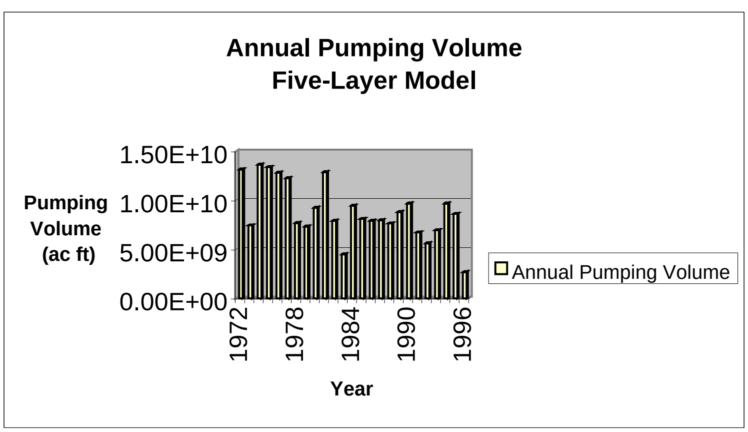
In addition to modifying the bottom elevation of the UAU, the MAU and LAU were truncated in the east Phoenix area where recent drilling indicated that neither unit exists. Although the exact eastern terminus of each of these units has yet to be determined, it is generally accepted that the units pinch out between 16th Street and 24th Street. In the CPM characterization, these units were truncated in this area.

3.5 SOURCES AND SINKS

Sources and sinks include all stresses on the aquifer system. A source (or inflow) is defined as a mechanism by which water is added to the groundwater aquifer. A sink (or outflow) is a mechanism by which water is removed from the aquifer. Sources include recharge and flow across model boundaries. Sinks include pumping wells and flow across model boundaries.

3.5.1 Pumping

Groundwater pumpage represents the major outflow from the groundwater system within the CPM study area. The annual pumping data were obtained from the primary agencies withdrawing the water (SRP and RID) from the ROGR database, from the ADWR files for the SRV, and from the VWR files. If surveyed state plane coordinates were not available for a well, coordinates were assigned by placing the well in the center of the quarter/quarter/quarter section



as listed in the ADWR 55 file. The total annual pumping for 1972 through 1995 is shown below. The pumping total for 1996 is for half of the year.

This graph shows the pumping within the CPM area in acre-feet per year. The earlier graph in Section 3.0 showed pumping for the entire SRV in thousands of acre-feet per year. The pumping patterns for the SRV and the smaller CPM are similar. In general, pumping in the CPM is less than 20 percent of the total SRV pumping.

There are 335 wells pumping water within the CPM area. Pumpage is divided between municipal and agricultural uses with these uses making up over 90 percent of the total. The remainder of the pumping is for industrial and private uses. Figures 24 through 28 show the locations of pumping wells in each of the five model layers. Appendix C lists the well locations and annual pumping volumes. Appendix D lists construction information for the wells.

Of the 335 pumping wells within the CPM area, 15 wells extend into the LAU. Ninety-two extend into the MAU and are screened across both the MAU and UAU. The remainder are screened only within the UAU. Well yields range from large diameter irrigation wells that can pump 2500 gallons per minute (gpm) to small diameter monitor wells that are only pumped during sampling. Well construction is highly variable depending upon when the wells were installed and for what purpose. Older wells are mills-knifed, stovepipe casing while newer wells use machine slotted or wire wrapped screen. These variations in well design can significantly affect the layers delivering water to the well. More efficient wells using wire-wrapped or louvered screen adjacent to high conductivity zones can produce large volumes of water with little drawdown.

Flash static water levels measured in an efficient well may be closer to true static than those in less efficient wells. The term “static water level” is assumed to represent a measurement taken when the water level in a well has stabilized and is only under the influence of atmospheric pressure. A “flash static” is a measurement taken shortly after a pumping well has been turned off and the water level is still recovering to a true static condition. This commonly occurs in municipal and irrigation company wells when the individual facility which may have been pumping for months is taken out of service for a few hours and a water level measurement is taken and recorded prior to starting the pump up again.

Many of the wells are screened across multiple aquifers so pumping needed to be allocated between the aquifers. The method used assigns pumping to an interval based upon the length of screen in that interval and the relative K in different layers. A higher conductivity zone will produce more water than a lower conductive zone.

There is a discrepancy between the pumping volumes used by the ADWR in the SRV model and those collected from SRP, RID, COP and City of Tolleson by the CPM team. ADWR estimated pumpage based upon reported pumpage plus an estimate of the volume pumped from exempt wells (wells with a pump capacity less than 35 gpm).

In the SRV model, exempt wells were assumed to pump 10 AF annually (the maximum allowed by law). Because the pumping could not be verified, and the small likelihood that many of these exempt well registrations represented functional wells, the exempt pumping was considered minimal and it was not included in the CPM total. The actual pumpage estimate from the water users is used in the CPM rather than the data developed by ADWR. Future modeling efforts that concentrate on site-specific areas may involve reexamination of exempt wells and their short-term effects on localized flow patterns.

3.5.2 Recharge

Recharge represents the major inflow to the CPM groundwater system. Recharge in the CPM area occurs when water at the land surface infiltrates and moves into the groundwater system. The sources of the recharge include the infiltration of excess irrigation water, leakage from irrigation canals and laterals, effluent discharge to river channels, and naturally occurring recharge from flood flows along the major drainages.

The locations of sources of groundwater recharge within the CPM area were identified using the land use maps (Figures 3 through 5) and the recharge for each source was estimated. The recharge values developed in the SRV model served as initial transient model inputs, although during model calibration some of these values were modified. The average recharge rate for each land use is shown on Figures 29 through 31. In the CPM, one recharge value is assigned to each node. This value is the sum of the recharge from canal seepage and agriculture less any losses to evapotranspiration (ET). In the CPM area, the ET losses are considered negligible because excurirrigation values already account for ET and canal seepage occurs below the roots zone of most plants. The recharge rates shown in Figure 29 through 31 are a composite for all land uses within a model node.

3.5.2.1 Agricultural Recharge

In much of the western portion of the CPM, irrigated agriculture remains the dominant land use. Fields are irrigated using sprinklers, rows, flood and furrow application, and excess irrigation water historically applied to these fields characteristically reached the local water table as recharge. How much of this water ultimately can be counted as recharge remains to be determined. Long, et. al. (1983) estimated that irrigation efficiency within the CPM area is 60 percent. As a result, 40 percent of the water is available to move beneath the plant root zone.

As agricultural fields are converted to urban uses and more water-efficient irrigation practices decrease the amount of water being applied for irrigation, recharge to the aquifer system is being impacted. Although these changes do affect the amount of return flow reaching the water table, irrigated agriculture still provides the main source of recharge within the CPM area.

None of the agencies in the CPM area have mapped crop type in specific fields. However, one of the more comprehensive attempts to quantify recharge from agricultural fields was provided by the ADWR in Modeling Report No. 8 (Corell and Corkhill, 1994). In this document, ADWR examined the volume of water applied to agricultural fields across the valley, subtracted the expected runoff from over-irrigation, computed the crop requirements, and determined the average volume of water available for recharge from each irrigated acre. Of course, this volume was not immediately available to the aquifer. An appropriate travel time had to be established between the land surface and the aquifer. This travel time, based upon the thickness of the unsaturated zone beneath the field, was termed the lag time for agricultural recharge and averaged ten years in the CPM area. On average, the volume of water available for recharge from each acre of agricultural field in the CPM area was 2.2 AF annually (Corell and Corkhill, 1994).

Without site-specific agricultural recharge data, the best source of data was the ADWR SRV Modeling Report No. 8 (Corell and Corkhill, 1994). This report contained estimates of the total volume of agricultural recharge for the entire SRV for 1973 and the period 1977-1991. In addition, ADWR had a figure (Figure 21 in Corell and Corkhill, 1994) which showed agricultural recharge for each square mile in the SRV model for the period 1983 through 1988. A method needed to be developed to apportion the total data given by ADWR for 1977 through 1991. Three steps were used to convert the ADWR data to the CPM. The first step totaled the agricultural recharge data from the ADWR report for the sections within the CPM area for the period 1983 through 1988. This total was 489,000 AF. The second step divided the CPM recharge (489,000 AF) by the recharge for the entire SRV model (3,426,261 AF) to arrive at a weighting factor of 14.3 percent. The third step allocated recharge in the conceptual model for the years 1973 and 1977 through 1991 by multiplying the weighting factor by the estimated total recharge for the SRV for those years. This process provided an estimate of agricultural recharge for the conceptual model.

Agricultural recharge for the years 1971, 1972, and 1974-1976 was estimated at 120,000 AF/yr based on the general trend of the calculated recharge data for 1968, 1973, and 1977. Agricultural recharge for 1992-1996 was estimated by plotting the data for 1989, 1990, and 1991 using a best fit straight-line trend.

The agricultural recharge rate used in the SRV model varied by area but averaged 1.92 ft/year for each acre of agriculture. This value was used initially in the CPM but was revised during model calibration to 1.82 ft/year to match available data.

In addition to establishing a rate of recharge, ADWR modified the process of direct recharge by applying a delaying factor to account for transit time of the infiltrated water through the unsaturated zone. This delay factor was implemented primarily to account for water in transit as agricultural areas are urbanized. ADWR assigned a lag time of less than 2.5 years for a depth to water less than 50 ft and a lag time of from 5 to 2.5 years for depths to water of 50 to 100 ft.

This method was not used in the CPM because more than two-thirds of the modeled area is urbanized and is not affected by agricultural irrigation. A lag time for irrigated land did not apply in those areas. In addition, more than half of the model area had depths to water less than 60 ft with another quarter of the area with depths to water of less than 100 ft. In addition, the model started in the middle of a 10 year period when agricultural pumping volumes were similar. The volume of water that needed to be "lagged" at the start of the model was similar to that being applied during that year.

A general reduction in agricultural acreage within the CPM area with time and more water efficient irrigation practices have decreased the volume of agricultural recharge. Given these conditions, it appeared that the volume of water reaching the aquifer within the CPM area would not vary significantly with time, but rather the most significant variation would be spatial, as agricultural land were urbanized. As a result no lag times were applied to agricultural recharge.

3.5.2.2 Urban Recharge

Over time, considerable effort has been expended to examine the extent and volume of recharge that might be derived from urban areas. Most of these investigations focused on areas receiving irrigation water from the SRP and, more specifically, those areas incorporating lakes or large expanses of irrigated landscaping (Corkhill, et. al., 1993). After reviewing these investigations and comparing the water-use characteristics of the areas examined with those existing within the CPM, WESTON determined that the impact of recharge from the majority of urban sources within the CPM is negligible.

Few urban lakes or heavily landscaped areas exist within the CPM area and those that are present do not appear to be large enough to contribute significant quantities of water to the aquifer. One possible exception is the Thunderbird Golf Course located along the north flank of South Mountain. At this location the water table is close to the land surface and underlying sedimentary deposits are coarse enough that recharge can occur rapidly. Contributing to the assessment of no urban impact are turf irrigation restrictions (ADWR, 1991), the lack of control over application rates and the presence of well developed caliche layers, which impede the downward movement of percolating return flow.

Recharge from urban areas was assumed to be negligible except in the Arcadia District in the northeastern part of the CPM where water levels are shallow and flood irrigation is used. Urban irrigation in the majority of the CPM area has minimal impact on recharge compared to agricultural irrigation because most excess urban irrigation run off is intercepted by storm sewers.

3.5.2.3 Canals

Canals have transported water for irrigation purposes within the CPM area since before recorded history. Present day canal systems convey a combination of groundwater and surface water from the Salt River (when available) from the eastern portion of the valley to agricultural users in the west. Over time, these canal systems have evolved from simple earthen ditches to concrete lined waterways conveying thousands of acre-feet of water annually. The canals constitute a source of recharge to the local aquifer system. Unlined (earthen) canals, contribute substantially more water to the aquifer than lined channels. Concrete lining, however, does not entirely eliminate seepage from these systems. Figure 32 shows the approximate years when reaches of the canals were lined.

There are five major canals within the CPM transmitting water for irrigation, the Grand Canal, Roosevelt Canal, Western Canal, North Branch of the Highline Canal and the Arizona Canal (Figure 1).

The infiltration rates for the canals and laterals within the CPM area were taken directly from the SRV model (Corkhill, et. al., 1993). The rates were developed by the SRP and the Bureau of Reclamation for lined and unlined canals. According to SRP, the rate for unlined canals and major laterals ranged from 0.52 ft^3/ft^2/day in 1977 to 0.25 ft^3/ft^2/day in 1988. The decrease in rate was a result of the gradual lining of the canals. The Bureau of Reclamation estimated that infiltration rates for lined canals ranged from 0.05 ft^3/ft^2/day to 0.24 ft^3/ft^2/day (Bureau of Reclamation, 1976). The canal recharge rates in the CPM were calculated based upon when the canal was lined and on the percentage of the canal present in a model node. Recharge from canal laterals was not explicitly modeled.

The values developed by ADWR for canal recharge were incorporated directly into the CPM water budget (Corell and Corkhill, 1994). ADWR estimated canal recharge by calculating the wetted canal area per section and assuming an infiltration rate per square foot of wetted area. Infiltration rates were either provided specifically for each canal by the irrigation districts or obtained from other sources. Canal recharge from 1970-1977 and from 1989-1996 were approximated directly from 1978 and 1988, respectively.

3.5.2.4 Salt River

The Salt River is the largest surface drainage feature in the CPM area. Although dry during most of the year, winter and early spring frontal thunderstorms, coupled with runoff from melting snows along the upper watershed, can produce floods. These events, although short in duration, contribute measurable recharge to the riparian aquifer.

The Salt River has historically played a major role in recharging the groundwater system in the CPM area. Prior to the construction of upstream dams, the river was perennial (Lee, 1905) and water was diverted from the channel for irrigation. During this time, the river was in direct hydraulic connection with the aquifer and the stream provided a relatively continuous source of recharge.

As flows in the river diminished with the construction of upstream reservoirs, the Salt River played an increasingly smaller role as a source of recharge. Groundwater pumping gradually lowered water levels in the CPM area until the magnitude of pumping rather than river flow, had the greatest impact on local water levels. The Salt River did not entirely vanish as a source of recharge. Periodic storm flows result in uncontrolled releases from the upstream reservoirs and the river courses again through Phoenix.

Several attempts have been made to quantify the amount of recharge received by the aquifer during these events. This was not an easy task. First, there were no permanent stream gauging stations between the Granite Reef diversion dam and the confluence of the Salt and Gila Rivers. As a result, all measurements were "real time" and subject to a higher degree of measurement error. In addition, if the year was wet enough to produce flood flows on the Salt, there was usually sufficient precipitation to reduce the need for heavy irrigation pumping. To maximize the use of available water within the SRV and divert some of the storm flows to beneficial use, the SRP occasionally offers “free water” to its member lands. This increased irrigation applications, decreased pumping and increased recharge from agricultural lands. As a result, observed rises in water levels in wells adjacent to the river during flood flows could not be entirely attributed to recharge from the river.

The following paragraphs provide a synopsis of the information in various reports dealing with the recharge characteristics of the Salt River during storm flow events.

One of the better-documented attempts to measure Salt River recharge was undertaken by Briggs and Werho in 1966. Between April 19 and 25, 1965, a controlled release of water from Bartlett Reservoir resulted in flow over Granite Reef Dam into the normally dry channel of the Salt River. To monitor the reduction in flow volume with distance downstream, gauging stations were established at 48th street, 16th Street and 7th Avenue. The results of these measurements indicated that nearly 75 percent of the water was lost before 48th Street due in large part to the availability of unsaturated material near the stream channel. Little additional water [less than 10 percent, 160 cubic feet per second (cfs)] was lost between 48th Street and 16th Street, while the gravel pits between 16th Street and 7th Avenue stopped most of the remaining flow. Less than 100 AF crossed 7th Avenue. Infiltration rates in the stream channel were calculated to average 1.1 ft/day.

As a result of this flow, water levels rose dramatically in wells within several hundred feet of the river. Although water levels also rose in wells farther away from the river, not all of this rise could be attributed to inflow from the stream as local wells had been shut down and at least a portion of that rise could be attributed to recovery of the local water table. According to the authors, “the data for all but one observation well are insufficient to distinguish the rise in water level due to recharge from the rises due to other causes, such as a reduction in pumping or increased loading on an artesian aquifer.”

Few researchers revisited this issue until 1980 when Bales, Schulten, and Pewe published a paper entitled “Ground Water in the Tempe Quadrangle, Maricopa County”. Although their research area only bordered upon the CPM, many of their observations and conclusions relate to the issue of recharge anywhere in the Salt River system. In particular, they determined that "…when water is available on the surface in the river valley, water users usually turn off their pumps. With the pumps off, the water levels in the wells rise in response to the ground water returning into the dewatered cones of depression…". In addition, they postulated that "entrapped air beneath the descending wet front may hold water levels artificially high for a time." Their research also determined that finer materials suspended in the stream flow are carried into the underlying alluvium with percolating water and clog available pore spaces with time effectively reducing the rate of recharge.

Concurrent with the Bales, et. al. report, Mann and Rohne (1993) were examining streamflow losses and changes in groundwater levels along the Salt and Gila Rivers near Phoenix. Mann and Rohne examined the flood events of February 1978 to June 1980, which totaled 5.45 million AF. They concluded that the total streamflow losses in the 74-mile reach between Granite Reef and Gillespie Dams were at least 474,000 AF. During that same time period, groundwater pumpage in the area was reduced by about 35 percent (1.9 million AF). Water levels were measured in 169 wells that tap the permeable deposits along the Salt River. Water levels rose from 1 to 145 ft in 157 wells and declined 1 to 43 ft in 11 wells with the greatest rise occurring near the Salt River. The average 35-foot rise in water levels was attributed to both recharge from the Salt River and a reduction in pumpage. The data collected allowed determination that the average infiltration rate in the CPM area was 0.45 ft/day.

In 1983, Turner prepared a report on incidental and natural recharge in the Phoenix AMA to aid the Phoenix AMA in developing strategies to achieve the management goal of safe yield mandated by law (Turner, 1983). In formulating his conclusions, Turner reviewed flood flow data spanning the period from 1911 to 1978 and reports by other authors analyzing these flood events. His overriding conclusion was "Mann and Rohne (1983) have estimated that between February, 1978, and May, 1980, 5.45 million AF of flood flows were diverted into the Salt River below Granite Reef Diversion Dam. Of this total, only 474,000 AF of water actually recharged the groundwater system in the SRV. This is only 9 percent of the total flood flow.…from the standpoint of quantities and the irregularity of occurrence, flood flows in the Salt River do not produce significant annual recharge."

Turner's work was followed by the development of the SRV model by Corkhill, et al., in 1993. In this report the authors examine historic records of flow in the Salt River and its tributaries and past reports analyzing this data. They concluded that flows less than 100,000 cfs stayed within existing banks. Using an infiltration rate of 0.91 ft/day multiplied by the wetted area, they estimated that the average annual recharge along the Salt River from Granite Reef Dam to Tempe Butte was approximately 12 percent of the annual Granite Reef Dam discharge and that another 12 percent infiltrated between Tempe Butte and the 91st Avenue WWTP. Only minor amounts of water were assumed to infiltrate downstream of 91st Avenue due to high groundwater levels.

In 1995, Eric Zugay examined recharge and mixing in groundwater along the Lower Salt River. His conclusions are based upon data compiled from numerous monitor wells along the Salt River during periods of high flow. Although the bulk of his work deals with the area east of Tempe Butte, he does cover the CPM area. In his thesis, Zugay concluded that recharge from storm flows depends in part upon the thickness of the vadose zone below the stream channel. If the available pore space is already filled with water, at least some of the available recharge will be rejected. He further determined that recharge along the Salt River was affected by channel geometry. The broad channel east of Tempe Butte allowed for greater recharge than the more channelized section through Phoenix. For these reasons, he concluded that "much larger amounts of recharge occurred between Granite Reef Dam and Tempe Butte than downstream of Tempe Butte, because of a thicker vadose zone and wider stream channel width".

The underlying conclusion of all of this past research is that, within the CPM area, recharge from the Salt River storm flows is highly localized and of little consequence from a volumetric standpoint. Stormflows are important in changing the direction of groundwater movement that may be experienced as a result of sudden rises in the water table.

The first step in evaluating recharge from the Salt River in the CPM area was to determine when the river would have historically produced a flow through the area given the amount of recharge characteristic of the stream channel above Tempe Butte. Records of historic flows were accessed to determine which might have been expected to produce flow in the CPM area. In addition, in 1990 ADWR examined the flood flows of 1983 to 1985 (Corkhill et al 1993).

Based upon this analysis, ADWR determined that, during these flow events slightly more than 320,000 AF of water were recharged between Granite Reef Dam and Tempe Buttes.

Using this as a threshold value, WESTON assumed that any annual flow in excess of 320,000 AF would have produced flow in the CPM area. This is not meant to indicate that lower, shorter duration flows would not reach the CPM area. It simply provides a marker for years in which the Salt River should provide recharge to the groundwater system. Table 1 shows the estimated annual releases from Granite Reef Dam for 1972 through 1993. As seen in the table, there are 8 years during which flow could have reached the CPM area and provided recharge to the groundwater. For 1994 through 1995, WESTON assumed the river did not provide recharge within the CPM area. Table 2 shows the corresponding time periods when the river package used in the model was turned on to simulate flow in the river.

3.5.2.5 Sewage Effluent from Wastewater Treatment Plants at 23rd Ave and 91st Ave

The only portion of the Salt River experiencing perennial flow is the downstream reach from each of the COP WWTP. At both the 23rd Avenue and 91st Avenue facilities, treated sewage effluent is discharged from the WWTP to the Salt River. Below the 23rd Avenue WWTP, flow continues in the Salt until about 67th Avenue (Corkhill et al 1993). Flow resumes below the 91st Avenue plant and continues beyond the western limits of the CPM area. Groundwater recharge from these effluent flows is evident in the shape of the water table contours for the area. The annual discharge from the 23rd Avenue WWTP to the Salt River is shown in Table 3.

Although RID diverts a portion of this effluent to their canals for irrigation use, according to RID records, these diversions were minimal until late 1995.

3.5.3 Groundwater Underflow

Another major component of the water budget is the movement of groundwater into and out of the model area as underflow within the aquifer system. In the CPM area, it appears that at least some groundwater inflow is present within the system. Although shallow bedrock produces a groundwater divide along the eastern and northeastern borders of the CPM area, some flow does occur across these boundaries. All flow within the system is to the west and northwest toward the major pumping centers in the Tolleson and Luke Air Base areas.

Groundwater outflow does occur along the CPM western boundary and during various times of the year. It is difficult to quantify the underflow in the CPM area due to the transient nature of water levels in the area and the limited water level data. Water level maps from 1972, 1982 and 1991 showed minimal inflow and outflow across the CPM boundaries, particularly along the northern, eastern, and southern areas. It appeared that flow across the western boundary depended on the timing and rate of pumping. Sometimes it could be into the model area while other times flow was not.

3.6 WATER BUDGET

The preliminary water budget for the CPM study area is a summary of the various components of groundwater inflow and outflow. The components include recharge, pumpage, and storage change, which is treated as a residual. There was no preliminary estimate of underflow due to the difficulty in selecting a representative hydraulic gradient for the model period. Water level data for 1972, 1982 and 1991 showed minimal flow across model boundaries for those time periods. Drawdown cones from pumping wells intersected the western model boundary indicating capture of outflow. This does not mean that underflow doesn't occur, just that the uncertainty was considered too large to try to estimate a volume from the existing data. A conceptual groundwater budget for the CPM study area for the 25 years from 1972 through 1995 is presented in Table 4.

4.0 COMPUTER CODE DESCRIPTION

The conceptual model developed in Section 3.0 provides information on the aquifer system needed before a computer code could be selected for the CPM. It described the physical properties of the Central Phoenix aquifers, as well as the complex interaction between the stresses imposed on that system such as pumping and recharge. It describes the locations of these stresses and any changes in them with time. As shown in the conceptual model, the Central Phoenix aquifers are heterogeneous, the stresses are transient, and groundwater flow occurs both horizontally within a geologic unit as well as vertically between units. The conceptual model, although a good summary of existing conditions, does not provide a means of demonstrating aquifer responses to future changes.

To use the conceptual model information to predict future movement in the Central Phoenix area requires some means of using past aquifer responses to stresses to predict the future aquifer responses to stress. This is accomplished using a mathematical equation describing the processes involved in three-dimensional groundwater flow within the aquifer. The equation is a simplification of the real system because it must perform each calculation at a discrete location within the aquifer. The general form of the mathematical equation is (McDonald and Harbaugh, 1988):

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial y}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t} \pm R$$

Where K_x, K_y and K_z are the components of K in the horizontal (x,y) and vertical (z) directions, h is hydraulic head, t is time, S_s is specific storage and R is a general source/sink term. The equation states that the change in head at a x,y,z location is equal to the change in storage at that location plus any changes in the recharge or discharge from that location.

The solution of the three-dimensional partial differential flow equation is accomplished numerically using a computer program that uses algebraic equations to approximate the solution to the partial differential equation. A numerical model such as the CPM simulates groundwater flow indirectly by using site specific data in the mathematical equation that describes the physical processes influencing groundwater movement in the aquifers. The computer code does not explicitly account for every complexity within the hydrologic system but uses a numerical technique, such as finite differences to solve the algebraic equations.

An example is provided of the steps involved in developing a finite difference program. Because it is assumed that the continuity equation is valid for groundwater flow, it is assumed that the sum of all inflows and outflows must be equal to the change in storage in an aquifer. The easiest way to visualize the flow equation is to think in terms of a cube of aquifer material. Under steady-state conditions, the flow into the block equals the flow out of the block and there is no change in storage (heads do not change in the block). This means that the right side of the above equation equals zero. Under transient conditions, the flow into the block and the flow from the block are not the same but result in a difference that is equal to a change in the volume of water stored in the block. The change in storage can be either negative (drawdown) or positive (recovery).

The partial differential equation is simplified by solving for discharge across the block face, assuming that head is known at one location and solving for head at adjacent blocks. Flow is calculated for all six faces of the block. The heads in each block in the grid are then calculated in an iterative fashion until the absolute value of head change between each iteration is less than or equal to some assigned value (for example, the error for closure is typically defined as 0.01 ft). If a large number of iterations is needed before the error between head calculations approaches the specified closure, then this is an indication there may be a problem with the conceptual model used to set up the model, the starting data, or the model grid may be causing problems in the solution because of numerical dispersion (Anderson and Woessner, 1992). The model may show dispersion (increase in head change) rather than convergence (decrease in head change) because the simplifying assumption made to solve the flow equation may not be reasonable for the problem.

4.1 SELECTION OF A COMPUTER CODE

The selection of a computer code or program that will be used to create a groundwater model depends upon several factors (Anderson and Woessner, 1992) such as the:

- Purpose of the model
- Ability of the code to simulate aquifer conditions under two- or three-dimensions and confined or unconfined conditions
- Ability of the code to simulate aquifer stresses, whether transient or steady-state
- Flexibility of the code to simulate boundary conditions
- Numerical method employed to solve the flow equations
- Reliability of the code
- Acceptance by the regulatory community

For the CPM, the factors listed above are as follows:

- The model should be able to predict groundwater movement in the future.
- The hydrologic system in the Central Phoenix area is three-dimensional with interconnected multiple layers having different hydraulic parameters. The upper layer is unconfined, the deeper layers are confined or semi-confined.
- There are 335 pumping wells withdrawing water from all five layers. Flow rates vary with time. Recharge is from the Salt River, irrigated fields, and canals. All are transient.
- The CPM does not abut hydrologic boundaries; therefore, the model must be able to simulate flow across the model boundaries. Some boundaries may be affected by transient changes outside the model.
- Because the CPM will be used on desktop computers by non-modelers, the numerical method employed to solve the flow equations needs simple data input and must be stable.
- Because the CPM will be used by future staff at ADEQ who may be unfamiliar with the numerical aspects of the model, the program must function without numerical or program errors.

- Because the CPM will be used by the ADEQ to evaluate the efficiency of future remedial alternatives, the computer code must be acceptable to the stakeholders as well as by the regulatory community.

All of these factors were considered before selecting the USGS's computer program MODFLOW (McDonald and Harbaugh, 1982) for use in the TLM and the modified version of MODFLOW, MODFLOW-SURFACT (HydroGeoLogic, Inc., 1996) in the FLM. The pre/post processor Groundwater Vistas (GWV) (Environmental Simulations, Inc., 1998) is used to facilitate data entry and the analysis of model results.

4.2 MODFLOW ASSUMPTIONS

MODFLOW, as distributed by the USGS, is a public domain, three-dimensional, finite-difference program for solving the equations that define groundwater flow. MODFLOW is a block-centered program. The aquifer must be subdivided into rows, columns and layers to describe the horizontal and vertical variations in the aquifer. The blocks or nodes created by the three-dimensional grid are defined at the center of a node. Each parameter can have only one value per node for any period of time; therefore, all aquifer parameters, hydrologic data, and inflow or outflows are averaged for each node. All program calculations, such as drawdown and head, are determined for the center of the node.

The basic features of MODFLOW described above remain the same for MODFLOW-SURFACT (version 1.2). But SURFACT includes several enhancements and additional packages that have been added to the standard MODFLOW program. These enhancements include the ability to reallocate pumping from wells that tap multiple layers in the case where shallower layers dewater and the pumping needs to be reapportioned between deeper, saturated layers. It also includes a revised resaturation calculation. SURFACT also provides the ability to automatically recalculate time-step parameters, aiding in model convergence.

GWV provides several capabilities not available when using MODFLOW as a stand-alone program. The graphical interface in GWV facilitates the entry and display of data and model results. In addition, GWV allocates pumping to multiple layers and calculates and displays model calibration statistics and hydrographs.

Standard MODFLOW packages used in the FLM include the Basic, River, Well and General-Head Boundary. Additional SURFACT packages used include the Block Centered Flow 4, Fracture Well, and Automatic Time Step. Although the SURFACT Recharge and Seepage Face package was used, only the MODFLOW variables were used. Table 5 provides an explanation of the purpose of each package.

4.3 LIMITATIONS

As with any computer code used to simulate groundwater flow, there are inherent limitations forced on the model by the simplifications made when converting the partial differential equations to algebraic equations solved by the finite-difference method. For example, hydraulic parameters must be averaged for a node within a layer. So, to increase vertical or horizontal detail in a model, the node size and layer thickness need to be decreased. Sublayers may need to be created within a hydrologic unit to increase the definition of the groundwater movement. A block-centered, finite-difference program calculates one head per node in a layer. If vertical movement is important, many sublayers may be needed to actually simulate the vertical movement. Other limitations include those that are specific to the program used, in this case, MODFLOW.

For example, MODFLOW does not actually calculate three-dimensional flow but uses a pseudo-three-dimensional flow scheme in which flow between layers is calculated using a vertical conductance term. Other limitations of standard MODFLOW include the inability of the program to reallocate pumping in wells that tap multiple layers from shallow, dewatered layers to deeper, saturated layers. For example, a 500 ft deep well may tap three different model layers that are hydraulically connected. The total discharge from the well is known, but the percentage of water removed from each layer is not known, so the discharge to each layer has to be allocated manually. If the model is run and the uppermost layer is dewatered, the total pumping volume isn't automatically reallocated to the two layers that remain saturated. To determine how much water can be withdrawn from the upper layer without dewatering the layer requires that the pumping be reallocated between the three layers manually and the model rerun. This requires an iterative approach to modeling, where the model is run and the location of wells where shallower layers are dewatered is determined. The pumping is then reallocated manually to deeper, saturated layers and the model rerun. This process is repeated until a run is achieved where all of the pumping is in layers that remain saturated. This problem was eliminated for the CPM by using the SURFACT version of the Well package to reallocate pumping between layers.

MODFLOW also permits nodes in a layer to "go dry" as the heads are calculated to be below the bottom elevation of the layer. MODFLOW can attempt to resaturate the node during subsequent iterations; however, the equations used by MODFLOW tend to be unstable and may cause the program to not converge. The equations used in MODFLOW have been modified in SURFACT and the resulting resaturation scheme is more stable.

For a transient flow model like the CPM, data such as pumping or recharge change with time. The changes could be daily, but the finite difference scheme requires that a time period be selected during which one data value for each parameter will be used in the flow equations. Real time data for pumping or recharge must be averaged for a stress period. Although the stress periods should be small enough that they are representative of the transient changes, the number of stress periods must be juxtaposed against the time it will take the model to run.

4.4 SOLUTION TECHNIQUES

The solution technique chosen for the CPM is the Preconditioned Conjugate Gradient Package (Version 4) (PCG4) as written in SURFACT. The original PCG2 package written for MODFLOW was created in 1994 when computer storage and memory were a limiting factor in creating large groundwater flow models and the other two solvers in MODFLOW, SIP and SSOR, tend to not perform as well for large, complex models. The PCG4 solver used in SURFACT takes advantage of the recent increases in computer memory and provides a robust, efficient solver for large, complex models (HydroGeoLogic, Inc., 1996).

4.5 COMPUTER CODE EFFECTS ON MODEL

The assumptions inherent in creating the computer code affect the performance and resolution of a groundwater flow model. Although great strides have been made in computer storage and memory, there are still limits in the size of a groundwater flow model. It becomes a trade-off between the computer facilities, the amount of data available for a site, the grid spacing for the model, and the length of the model time steps. The smaller the grid spacing and the shorter the stress period, the more detailed information can be entered into and obtained from a model. However, smaller grid spacing requires significantly more data to develop the model, the model uses more computer storage, and it takes more time for the model to run. The CPM, at 144 rows by 80 columns and 5 layers has roughly 57600 nodes of 660 ft wide by 660 ft long with varying thickness. Data must be defined for every active node in the model.

A similar constraint on model performance is the necessity to solve the flow equations with time. The period of interest needs to be subdivided into smaller intervals during which the equations are solved. The seasonal nature of pumping in the western portion of the model dictated that some seasonal variation in the length of the stress periods was necessary. This resulted in dividing each year into three unequal stress periods based upon the volume of water pumped by RID, the major pumper in the western portion of the model area. Average rates for pumping and recharge were set for each stress period in every node where either process occurred. This means that water level data may not agree with model results because a well assumed to pump an average rate for 200 days may have only pumped 30 days at a higher rate. This also impacts recharge from the river because a river node is either on (the river is flowing) or off (the river is dry) for an entire stress period.

The solver used in the CPM, the PCG 4, was specifically written for SURFACT. PCG4 does not require iteration parameters other than closure tolerance limits and a maximum number of solver iterations.

5.0 MODEL CONSTRUCTION

Model construction begins with the definition of the model domain, the creation of a model grid, and the subdivision of the simulation time into stress periods. Once the model grid is constructed, it is overlain on the CPM basemap, and the information from the Conceptual Model is used to create the data arrays that are input to the computer code. The stress periods are used to create the distribution of transient data (data that change with time).

The input data files for the CPM are stored on a CD-ROM that will accompany the final report. Hard copies of the model input and output are not included in the report due to their large sizes.

5.1 MODEL DOMAIN

The CPM uses a uniform grid of 80 rows by 144 columns (Figures 33 through 37). Nodal spacing is 660 ft. This grid spacing closely matches the Cadastral numbering system used by the USGS and ADWR to locate wells. By using this spacing, it is easier to locate new wells in the model grid when the only well location information that is given for the well is the cadastral location to the ten acre, quarter/quarter/quarter section, rather than state plane coordinates.

The five hydrologic units modeled are the two layers comprising the Upper Alluvial Unit (UAU_1, UAU_2), two layers within the Middle Alluvial Unit (MAU_1, MAU_2) and a portion of the LAU.

The model units are days and feet with all flow rates entered as feet per day per model mode.

5.2 SIMULATION PERIOD

The CPM simulates flow from 1972 through 1996 for a total of 25 years. Each year is subdivided into three unequal stress periods. Each stress period has from 7 to 14 time steps. The seasonal division was based on work done for the VWR model (VWR, 1997). The length of each stress period was verified by reviewing monthly pumping data provided by RID for 1992 through 1998 (Table 6). The new data confirmed the pattern selected for the VWR model:

January & February: 10% annual pumping (59 days)
March - September: 84% annual pumping (214 days)
October - December: 6% annual pumping (92 days)

Table 7 shows the length of each time step and the elapsed time.

5.3 DATA SOURCES

The data used in the CPM input arrays are from a variety of sources as described in Section 3.0. These sources include the Phase I database (WESTON, 1997), the ADWR SRV Model (Corell, 1994 and Corkhill, et. al. 1993), the ADWR Registry of Grandfathered Water Rights database, and files from the VWR WVB model (VWR, 1997). Unless specifically indicated in this text, the references for the data used in this model and the steps used to compile the data are listed in the Phase I database.

5.4 DATA ARRAYS

The aquifers in 1972 were under transient, not steady-state conditions. The water levels in 1972 were influenced by past pumping and recharge, and changes in water level occurred in subsequent years as a result of past activities.

Although only the UAU_1 is defined as unconfined initially, each of the five layers is assigned both a specific yield array and a storage coefficient array because all of the layers have the potential to become unconfined as water levels fall below the top of the layer. Because SURFACT is used to simulate the groundwater flow in the CPM, the layer types for all five layers are set to Layer code 3. This is a requirement in SURFACT. Layer code 3 indicates that all five layers are initially confined but switch to unconfined as soon as water levels drop below the top of each layer. The UAU_1 immediately switches to unconfined during the first model iteration but the other four layers stay under confined conditions until water levels drop below the elevation of the layer top. Layer code 3 requires that data arrays for K, bottom and top elevations and storage coefficient and specific yield be provided for each layer.

There are two types of data arrays used in the CPM, those that stay constant with time and those that change with time. Arrays that are defined once and remain the same for the entire model simulation period include:

- K for all five layers
- storage coefficient/specific yield for all five layers
- bottom elevations for all five layers
- locations of boundary conditions
- no flow locations
- constant flow rates and locations
- river node locations
- starting water level data
- calibration target data
- vertical conductance (VCONT)

Data arrays that change with time include:

- pumping
- recharge
- water levels at time-variant flow boundaries
- stress periods when there is river flow

Data arrays were created using several mechanisms. Random data such as water levels, and top and bottom elevations were entered into SURFER and gridded. Other data, such as K, were entered in GWV as regions of the same data. Point data such as pumping wells, boundaries and river locations were entered in GWV under the specific model package.

5.4.1 Boundary Conditions

The boundary conditions used in the CPM are shown in Figures 33 through 37. The three types of flow conditions described in Section 3.2.2, constant flow, time-variant flow, and no flow are defined in the model as wells (constant flow), time-variant flow (general head), and no flow (no flow).

5.4.1.1 Constant Flow

Constant flow boundaries were established along the eastern, northeastern and south-central borders of the model to reflect the recharge and inflow available to the system from adjacent areas. The flow rates were set based on the flows that crossed the borders in the steady-state model. Constant flux boundaries are simulated in MODFLOW as injection (inflow) or extraction (outflow) wells. This boundary is modeled using the Well Package.

5.4.1.2 General Head (Time-Variant Flow)

The northwestern, western and southwestern boundaries are set as General Heads Boundary (GHB), which are a head-dependent flow boundary (Figures 33 through 37). This means that flow across the model boundaries is calculated based upon the changes in head between the external boundary and the model. Input data required for each GHB are head at the boundary (some distance away from the model) and a conductance term. Flow across the GHB is calculated using Darcy's Law. The conductance term combines the K between the model and boundary with the distance between the model and the boundary and the area of flow. The missing component of Darcy's Law is the difference in head, which is established by subtracting the model-calculated head from the specified head at the boundary. The GHB provides more flexibility than either a constant head or constant flux boundary because flow across the boundary varies based upon the model calculated water levels. Care must be taken to ensure that the GHB does not act as a constant head providing either an unlimited source of water to the model or removing an unrealistic volume of water from the model. This can happen if the difference between the two heads becomes too large. Neither situation occurs in the CPM.

The starting boundary heads are set to the 1972 water levels at a distance of 5280 ft from the model boundary. The boundary heads were changed in 1982 and 1991 to reflect the changes in those water level maps. In addition, the heads along the northwestern part of the model were decreased by 10 ft in the second stress period of each year to simulate the effects of wells pumping outside the model area. The K used in the calculation of the conductance is set equal to the conductivity in the boundary node. The flow area is defined as the saturated thickness in the node for 1972 (and for each of the other two years) multiplied by the node width, 660 ft.

5.4.1.3 No-Flow

The model grid abuts the flanks of South Mountain in the southeast. This area is defined as a no-flow boundary, which means that there is no water entering or leaving the model because of the hydrogeologic conditions.

5.4.2 Hydraulic Conductivity Arrays

The UAU K array was initially set up for the steady-state model. It was modified during the steady-state calibration and the TLM development. This editing involved examination of each model run and comparison of calculated and measured water levels. If a discrepancy existed, the aquifer test data used to develop the K array in the area of the discrepancy were reexamined. If the data supported an adjustment in the array, the adjustment was made and the model rerun. If the data did not support modification of the conductivity array, the elevation of the bottom of the UAU was reexamined to determine if a greater thickness of upper alluvium were present. Again, if the data supported it, the thickness was adjusted to modify calculated heads. This process was repeated until a reasonable match was achieved between measured water levels and the model calculated water levels.

The UAU array used in the steady-state model was modified when the UAU was split into two sublayers. The UAU_1 has higher K; the UAU_2 has a lower K (Figures 38 and 39).

The K arrays for the MAU_1 and MAU_2 were set equal to those used in the SRV model, as was the LAU array (Figures 40 through 42) (Corkhill, et al 1993).

MODFLOW doesn't simulate vertical flow between layers explicitly but rather as a result of a leakance between layers. The vertical leakance (VCONT) is the Kv divided by the thickness of the internal between the layers (McDonald and Harbaugh, 1988). The thickness is defined as the midpoint of one layer to the midpoint of the layer below it. There are no data on Kv within the CPM area; therefore, the vertical conductivity was set to one-tenth the horizontal K. The thickness and VCONT are calculated by GWV.

The model sensitivity to VCONT is tested during the sensitivity analysis. Vertical anisotropy within a layer is not used in the CPM other than to assure the Kv is one-tenth the horizontal conductivity.

5.4.3 Specific Yield/ Storage Coefficient Arrays

Figures 43 and 44 show the specific yield and storage coefficient arrays for UAU_1 and UAU_2.

5.4.4 Bottom Elevation Arrays

The bottom elevation contours are shown in Figures 19 through 23. The grid from which the contours were created was read into GWV and one elevation read for each node in every layer. Individual nodes were edited in GWV to reflect some of the smaller scale features such as the bedrock high in the eastern portion of the model area.

5.4.5 Pumping

The pumping wells are simulated in the CPM as analytical element fracture wells. The majority of the pumping wells in the CPM are screened across multiple hydrologic layers, meaning a portion of the pumping must be allocated to each layer. GWV allocates the pumping from each well to a layer based upon bottom elevation of the well screen and the K of each layer tapped. For GWV to allocate pumping, the input data must include the top and bottom elevation of the well screen. If well construction information is not available for a well, it is assumed that the well is screened from the water surface to the depth of the well. Appendix C shows well locations, annual pumping volumes and top and bottom screen elevations as assigned for the model. Appendix D shows the recorded top and bottom screen elevations for each pumping well.

The FLM has three stress periods in a year to simulate the seasonal variation in irrigation pumping. Monthly pumping volumes were available for RID; therefore the average distribution calculated for RID was applied to the other irrigation wells. The multipliers for the pumping are the same as those used to split the annual time frame into seasonal stress periods. Ten percent of the annual pumping occurs during the first stress period.

Other information included in the pumping data input file includes the CPM number, the state plane coordinates, and the pumping at each well for each stress period. Each well in the file has the same number of pumping records whether the well pumped during every stress period or not. If there was no pumping during a stress period, the pumping rate was set to zero ft/day.

5.4.6 River Package

The FLM uses MODFLOW's River Package to calculate recharge from the river as a function of the conductivity of the channel alluvium and the relationship between river stage and groundwater elevation. It was assumed that perennial flow occurred in the river downstream of the 23rd Avenue WWTP to 67th Avenue and downstream from the 91st Avenue WWTP. Other portions of the river are turned on and off at the beginning of each stress period depending on whether there was sufficient flow in the river for recharge. The years when the river was considered active are shown in Table 1. The seasonal distribution of river flow occurred during the first two stress periods, unless it was known that the river flowed all year. This provides definite advantages when modeling an ephemeral river like the Salt River. The locations of the nodes used in the river package are shown in Figure 33.

River bottom elevations were set equal to land surface elevations shown on the USGS topographic maps. Without accurate data on river stage with time, the river stage was set at 0.15 ft above the river bottom. Although this stage is obviously too low during periods of high flow, it is a reasonable number considering the length of the time period during which flows are considered to occur. The river conductances were calculated by GWV. WESTON assumed that Kv's are one-tenth of the horizontal K and the thickness of the lower permeability material along the base of the river was one foot thick.

5.4.7 Recharge

Recharge is applied only to the UAU_1. The recharge array used for the period 1972 through 1987 is shown in Figure 29. A second recharge array was used from 1988 through 1994 (Figure 30). A third array was used in 1995 (Figure 31). The biggest change between the three recharge arrays is the conversion of land from agricultural to residential use, and the lining of reaches of the irrigation canals. Figure 32 shows the approximate years when reaches of the canals were lined.

5.4.8 Calibration Targets

A calibration target is defined as "a point in space and time where one of the model dependent variables has been measured" (Environmental Simulations, Inc., 1998). Transient calibration targets in GWV can be head, concentration, or drawdown. The CPM uses head values from the 1982 and 1991 water level data, as well as data from the well hydrographs. There are 156 locations in the CPM for which heads are available. The locations and water level data are listed in Appendix B. The distribution of target locations by layer is shown in Figures 45 through 49.

Many of these wells are screened across multiple layers. GWV assigns the calibration targets to the layer in which the bottom elevation of the screen occurs. Of the 156 calibration target locations in the FLM, 70 are RID, SRP or COP wells. That means that almost half of the locations with data are pumping wells. There is a potential difficulty in using water levels collected from pumping wells because the data may not represent true static water levels but rather a flash static. A flash static is measured when the wells are turned off, allowed to recover for a short period of time (usually a few minutes), and the water level measured. The water level is lower than a true static since the water levels are still recovering. Water level measurements that were anomalous when compared to the remaining data for that well were deleted from the target file. Anomalous data were defined as individual water level measurements that deviated from the remaining data by 40 ft or more.

The frequency of the data measurements ranges from weekly to once per year or every few years. Beginning in the 1990s, water level data were collected more frequently because monitor wells were installed for remedial investigations at many facilities within the area. However, the majority of monitor wells are installed within the shallower portions of the UAU.

Calibration targets can be weighted because the reliability and accuracy of all data aren't equal. At this time, all of the calibration targets in the CPM are weighted equally.

The data are entered in the model as elapsed time from the beginning of the model (days since January 1, 1972). The water level measurements used as calibration targets were not all measured on the same day. For example, the 1982 and 1991 data were measured over a two-month period. GWV accepts a time period during which all data will be considered. The time frame for the calibration targets for the CPM was ±30 days.

The residual or difference between the model calculated value and the measured value at the calibration target provides one way to evaluate the ability of the model to simulate the aquifer conditions. Another method for evaluating a model calibration is to compare water level contour maps generated with the observed data with model-generated water level contour maps. The objective is to qualitatively compare the flow direction, spacing of the contours and shape of the contours. The two maps should be similar. Both methods are used in the CPM.

5.5 MODEL SIMULATIONS

The modeling process follows an iterative sequence of steps. The first step is to run the model. The CPM is run on an IBM-PC. MODFLOW runs from within the GWV shell. SURFACT is run from a DOS window. The model runs take from 2.5 to 7 hours for the transient 5-layer model. Once the model run is complete, the modeler reviews the model mass balance. If the mass balance is reasonable and the mass balance error is small, the model calculated water levels and hydrographs are reviewed. This involves checking for the difference between the observed and calculated water levels, the shape of the water level contours and the correspondence between the observed and measured water levels in the hydrographs and on the contour maps. Each of these reviews provides information regarding the calibration of the model. Where there are discrepancies between the calculated and observed data, the conceptual model and the data used in the model must be reevaluated to determine if changes can be made to the data arrays. If changes can be supported, they are made in the data arrays and the model rerun. The process continues until the model results are acceptable. The CPM was considered calibrated when:

- the mass balance error was less than 1 percent
- the model calculated water level contours and the water level contours for the measured data are similar in shape and spacing
- hydrographs of calculated water levels and measured water levels are similar
- model statistics are reasonable. The standard deviation of the differences divided by the range in heads is less than 10 percent. The residual mean should be close to zero. The absolute residual mean (ARM) should also be close to zero.

Once a model is accepted as calibrated, a sensitivity analysis is run to evaluate the model's response to changes in the data arrays.

The modeling process for the CPM occurred over several years. Documenting every step in the process was critical to making sure that mistakes weren't made and work duplicated or lost. The process was documented in modeling logs that detailed changes to the model, in memoranda to the file describing decisions, and in interim reports describing work products. Every time a change was made to the model input files, the model was renamed. Changes could be as small as correcting a typographic error or as large as modifying a data array. The CPM model naming convention used the number of the run and the letters "sf" signifying SURFACT. The calibrated CPM is named 116SF (SURFACT without automatic time stepping) and 118sf (SURFACT with automatic time stepping). Although it appears that 116 transient runs were made, the numbering for the FLM began at 60. Numbers less than 60 were used for the TLM. The description of the input data files and the steps in running the CPM are in a readme file on the CD. The SURFACT input data files will not run in MODFLOW without removing the SURFACT specific parameters.

6.0 MODEL CALIBRATION

The calibration of a numerical flow model is accomplished by comparing:

- a model calculated mass balance to a conceptual mass balance
- model calculated hydraulic gradients and flow directions with measured gradients and directions
- measured hydrographs with model-calculated hydrographs
- measured calibration targets with model-calculated targets and the resulting statistics.

All of these comparisons are used in the FLM calibration. The final model run was named 116sf. A second model run with the same input parameters but using the Automatic Time Step package in SURFACT was used as the baseline for the sensitivity analysis. The use of the Automatic Time Step package increased the ability to complete the sensitivity runs.

6.1 MASS BALANCE

The MODFLOW mass balance is a summary of the model-calculated inflows (areal recharge, infiltration of river flow, and boundary inflow) and outflows (pumping and boundary outflow). MODFLOW also includes the change in storage in the inflow or outflow portion of the mass balance. MODFLOW subtracts the inflows and outflows to calculate a mass balance error. The difference between the model calculated inflows and outflows should be zero for a model that is numerically stable and is a reasonable representation of the aquifer system. Table 8 shows the cumulative mass balance for all stress periods for 116sf. The CPM mass balance for stress period 75 is shown in Table 9, as are the cumulative numbers from the Conceptual Mass Balance for 1972 through 1996. The inflow in the Conceptual Model was from recharge and was estimated to be 0.1428 E+12 ft^3 for the 1972 through 1996 period. This value included recharge from the WWTP. The model-calculated inflow from recharge and river packages is 0.2 E+12 ft^3. The difference between these two is the non-WWTP river recharge, which had not been included in the Conceptual Model. Other inflow in the model that was not estimated in the Conceptual Model was underflow.

The outflow in the Conceptual Model was from pumpage, which was estimated at 0.183745 E+12 ft^3 for the period 1972 through 1996. This total included pumping from wells that were just outside the final model boundary. The model calculated pumping is 0.17969 E+12 ft^3. The difference between the two is two percent. Underflow across the model boundary was not estimated in the Conceptual Model.

The mass balance error for the FLM is 0.17 percent. As expected, the major outflow from the model is from pumping (54 percent). Outflow across the model boundary is an order of magnitude less than pumping at 20 percent of the outflow.

The major recharge mechanism is from the infiltration of irrigation water and canal seepage (31.5 percent) with the second highest source from the river (28.5 percent). Inflow across the model boundary is 16 percent of the total inflow. The net change in storage in the model for the 25 years is three percent of the total volume of water. The net change in storage indicates water levels during the 25 year period have decreased.

A comparison of the conceptual mass balance and the model mass balance should show the two having similar volumes for all components (Table 10). That is true for recharge from agriculture and canals as well as pumping volumes. Boundary inflows and outflows were not estimated in the conceptual mass balance but at 10 percent and 20 percent of the volumes of water they are reasonable. The river recharge was also not estimated in the conceptual model but it turned out to be a major component of the model water budget. Combined with the river recharge number in the model mass balance is recharge from sewage effluent. Sewage effluent is approximately one-fourth of the total recharge volume over the 25 years. The river recharge (minus effluent) is approximately 14 percent of the flow from Granite Reef Dam over the 25-year period. Researchers estimated that 11.5 percent of the flow at Granite Reef Dam recharges between the Dam and the 91st Avenue WWTP for the period 1978 through 1988. If the data from 1980 are excluded from the calculations (because the outflow was greater than the inflow), the estimate of recharge is 16 percent of the Granite Reef flow. These estimates do not include inflow of urban storm runoff into the Salt within the CPM area. Stormwater runoff from the CPM area and the areas downstream from Granite Reef Dam contribute to river flow and recharge.

6.2 QUALITATIVE/QUANTITATIVE ANALYSIS COMPARISON OF WATER LEVEL MAPS

Figure 50 shows the differences between the 1982 measured water levels and the model computed water levels for all five layers. The residuals are color coded according to completion zone. A positive residual means model-calculated water levels are lower than observed. A negative residual means model-calculated water levels are higher than observed. The data available to calculate residuals are concentrated in the western two-thirds of the model area. Figure 51 shows the differences between the 1991 measured water levels and the 1991 model-computed water levels. The CPM-computed water level contours in general match the shape and direction of flow and hydraulic gradients are similar. The model-calculated water levels are smoother and don't show the deflections in water levels that are the drawdown cones around pumping wells. One pattern that is observed in the western part of the model area is that the 1982 model water levels are lower than observed but by 1991 the difference between the two is less. Prior to 1982, pumping volumes are estimates. After 1982, the water rights holder had to report pumping volumes to the ADWR.

6.3 CALIBRATION TARGETS

There are 156 locations in the FLM for which heads are available sometime during the 25-year period. The number of head measurements at each location varies, as does the depth at which the well is completed. Many of the head measurements are composites for multiple layers and not layer specific. The target locations in all five layers are shown in Figures 45 through 49.

GWV automatically calculates the difference between the measured heads and the model calculated heads for every model run. If a model calibration is exact, the residuals would be zero and a scatter plot, showing model values plotted against observed (measured) values, would show the data falling along a 45 degree line. A well-calibrated model will have a small residual with the data evenly distributed above and below the 45-degree line with no spatial bias in the data. That is, there shouldn't be a correlation between a group of positive or negative residuals and an elevation or geographic area.

Appendix E shows the residuals for every calibration target within the CPM. Figures 52 through 57 show the comparisons of observed versus model computed target values. Figure 52 shows the data for all five layers for all data. The plot shows a good relationship between the observed and computed water levels. The UAU_1, UAU_2 and MAU_1 also show reasonable results with data falling along the 45° line and little bias geographically. MAU_2 and LAU, with 6 and 11 data points, are not valid plots but are shown for completeness. Of the three layers, the MAU appears to be the best simulated because the regression line is very close to a 45-degree line.

Data for water levels measured in the three hydrologic units shows a difference in elevations between the three units. In general, water levels are higher in the UAU than in the other two units. The model also shows vertical differences in water level elevations.

6.4 SEASONALITY ISSUES

One of the goals of the CPM was to reproduce the seasonality in water levels shown in individual well hydrographs. There are several methods to evaluate whether the CPM simulates the seasonal changes. These include comparing model-predicated hydrographs with observed hydrographs and comparing the changes in water levels across the model area. The hydrograph comparison is discussed in the next section.

Figures 58 through 61 show the changes in water levels that occur across the model area for the four stress periods beginning in 1995 (70 through 73). Figure 58 shows the water level contours for all four periods. As expected, the water levels decrease during the second stress period (highest pumping volume) and recover during subsequent periods. These differences are shown in Figures 59 through 61, which show the differences between calculated water levels at the end of stress period 70 and subsequent stress periods.

6.5 DISCUSSION OF HYDROGRAPHS

In the CPM area, there are 156 wells that have measured water levels with time. The use of the wells in which water levels are available ranges from irrigation supply wells used by SRP and RID, to monitor wells installed at various facilities where contamination has occurred. The hydrographs referred to in the text are designed to show a variety of model responses. The interval along the y-axis is 5 ft. Of the ten hydrographs shown, 6 wells are completed in the $UAU_{1,}$ two are in the UAU_2, one is in the MAU_1 and one is in the LAU. All of the hydrographs show the seasonality in water levels in the CPM area.

The range in difference between observed and calculated water levels is –37 ft (model-calculated levels are too high) to 35 ft (model-calculated water levels are too low). Figures 63 through 72 show selected hydrographs from the model. The hydrographs demonstrate the problems in calibrating a model when some of the target water levels are measured in a pumped well.

RID-110 (completed in the UAU_2) is one of the better hydrographs for the FLM (Figure 68). There is good correlation between the measured and calculated water level data. Although some of the water level peaks are offset, this could be a result of the seasonal pumping distribution or the timing of the water level measurements.

SRP-048 (Figure 70) and SRP-060 (Figure 69), both completed in UAU_1, are irrigation wells. Individual correlation between data points looks good if two things are considered. First, the distribution of seasonal pumping for the SRP wells is based on RID pumping. SRP uses the wells to augment surface water flows in the irrigation canals, so the withdrawals from the wells may not follow the same pattern as RID. Second, there is no information on whether the measured water levels are true statics.

GOM-3 (completed in UAU_2) shows excellent correlation from 1981 on, but measured water levels are as much as 30 ft too high before that time (Figure 67). The question that is raised is the same as above, are pumping estimates in this area for the pre-1981 time period too high?

The same pattern seen in other hydrographs for the 1994/1995-time period is also seen here where the observed water levels are higher than calculated.

The hydrograph for MAS-1 (completed in UAU_1) shows excellent correlation between peaks and valleys (seasonal changes) between the model and computed water levels (Figure 71). However, the difference between the two varies from less than one foot in 1985 to as much as 20 ft in 1994. Many of the hydrographs show a discrepancy in the 1994/1995 timeframe, regardless of location in the valley. Generally there is good correlation in 1993, but something happens in 1994 that is not accounted for in the CPM. It is possible that flows in the Salt River during 1993 were responsible for this rise.

SRP 082 (completed in MAU_2) has model computed water levels that are too low in the 1980s but have a more reasonable correlation after 1982 when pumping was reported in the ROGR database (Figure 72).

All-021 (completed in the UAU_1) is a monitor well installed during the early 1990s in the eastern part of the CPM area (Figure 63). Data from 1993 are similar but 1994 and 1995 show the same difference between modeled and measured water levels. Again, something occurred in the CPM area in 1994 that is not accounted for in the model.

AVB46-01 (completed in the UAU_1) shows the similar discrepancy in water levels in 1994 and 1995 as the other target wells (Figure 66).

COP-338 (completed in the LAU) has a reasonable correlation between the modeled and observed data until 1995 when a small water level rise is observed in the measured data but not in the modeled data (Figure 65).

SRP-047 (completed in the UAU_1) is a good example of some of the problems with the calibration data (Figure 65). Observed water levels are lower than modeled in the 1970s, possibly indicating that they are flash static measurements. One data point in 1980 is 10 ft higher than the modeled data, but this could be caused by an incorrect pumping distribution in the model, a mistake in the water level measurement, or a problem with the model. By the mid

1980s, the observed water levels are lower than the model calculated water levels. This discrepancy could be caused by measurements that are flash static water levels. The reverse is true in 1990s where the observed water levels are as much as 10 ft too high. This change could again be caused by a problem with the pumping distribution in the well.

Hydrographs for the other wells are included in Appendix F. Wells having fewer than 3 water level measurements were not plotted. The data for these wells can be seen in the Residual Appendix E.

The change in water levels in a well can vary from more than 150 ft in a pumping well to less than 20 ft in a monitor well such as ALL-021.

6.6 MODEL STATISTICS

GWV uses the residuals calculated for the calibration targets to develop some statistics that can also be used to evaluate the model results. These statistics include:

- Sum of squared residuals
- Residual mean
- Residual standard deviation
- ARM
- Residual standard deviation divided by range in target value

The following description of the GWV statistics is summarized from the GWV manual (Environmental Simulations, Inc, 1998). The GWV calculated statistics are listed in Appendix E at the end of the residual table.

The sum of squared residuals is computed by squaring each residual and then adding the squares together. This number is not particularly useful for one model run, but can be used to compare the results from several runs. The objective is to minimize the number. For the CPM, the sum of the squared residuals is 1.05×10^5.

The residual mean is calculated by dividing the sum of the residuals by the number of residuals. For a good calibration, the negative and positive numbers should balance and the mean should be close to zero. However, this number should be used with caution because if negative and positive residuals are large, but evenly distributed, the mean could still be zero. The residual mean for the CPM is one foot.

A measure of the average error in the model is given by the ARM. The ARM is calculated by removing the negative signs from the residuals, summing the residuals, and then dividing by the number of the residuals. The ARM in the CPM is 7.2 ft.

The residual standard deviation is a measure of the range of the residuals. It essentially provides an indication of the range above and below a value. The residual standard deviation for the CPM is 9.3.

The residual standard deviation divided by the range in the target values provides a comparison of the errors to the change in head in the model. This value should be less than 10 percent for a good model calibration. The residual standard deviation divided by the range for the CPM is 4 percent.

Overall, the statistics for the CPM are good and meet the criteria originally established of a residual standard deviation less than ten percent and an ARM less than 10 ft.

6.7 DISCUSSION OF MODEL CALIBRATION

The CPM calibration is reasonable. The model appears to function reasonably well along the river and throughout the model interior. Differences in modeled and observed data are less than 10 ft in most areas where pumping does not occur (Figures 50 and 51). Comparing hydrographs and water level contour maps show the model reproduces the seasonality of pumping and water level changes in the area. Areas where calibration isn't as good include those along the northwestern corner and near some pumping wells.

6.8 COMPARISON OF ANNUAL FLOW MODEL WITH SEASONAL FLOW MODEL

Although the calibration of the TLM was never completed, there are major differences between the TLM and the CPM model results. The TLM could not reproduce the seasonal changes in water levels that occurred throughout the valley whether in response to pumping or river recharge. The CPM does reproduce these changes. River recharge effects were also not simulated well in the TLM because flow to occurred for the entire year, whether the river actually flowed the entire year. As more information on the hydrostratography of the UAU becomes available, it also becomes evident that the two layers in the UAU may respond differently to pumping. The TLM couldn't reproduce these differences.

An example of the differences between the two models is shown in Figures 72 through 75. These plots show the velocity vectors for 1995 for both the TLM and the CPM. The vectors for the TLM for the entire year are an average. The vectors for the CPM show that flow directions change with time through the year depending on which wells are pumping.

6.9 SENSITIVITY ANALYSIS

A sensitivity analysis is designed to test the uncertainty in a groundwater flow model associated with the uncertainty involved in estimating data for the model. Uncertainties include those associated with measuring aquifer parameters, defining boundary conditions, and stresses. Examples include applying point measured data such as K or bottom elevations to a larger area, the indirect measurement of recharge volumes and rates, and even in estimating the volume of water pumped when the wells are not metered. The problems with water level measurements have already been discussed. The sensitivity analysis is designed to evaluate the effect of a single change in some parameter in the calibrated model on the model results, whether a mass balance error, a change in hydraulic gradients or the magnitude of change in heads. It provides a means of evaluating where additional data collection may result in more useful information to the model. For example, a model with little sensitivity to K, but a greater sensitivity to pumping volumes would benefit in better quantification of pumping volumes rather than additional aquifer tests.

The sensitivity analysis for the CPM was designed to test the calibrated model sensitivity to the changes in the following parameters:

- Agricultural recharge rates
- Canal recharge rates
- Storage coefficient/Specific Yield
- River Conductance
- Discharge volume for 23rd Avenue WWTP
- Horizontal and Kv
- Pumping Rates
- General Heads Boundary Conductance

Seventy-three runs were made where one parameter was changed in the calibrated model and the model rerun. Table 11 lists the model run names, the parameter changes and the statistics associated with each run. The results from the final calibration run, SF116, are also listed for comparison. Of the 73 runs, 10 did not converge. The runs that did not converge were for changes in K. Figure 76 shows the sensitivity of the model to changes in recharge. Figures 77 through 83 show the comparison of the sum of the squares for each run for each parameter as compared to the calibrated value. The figures are arranged in order of model sensitivity to the parameter.

Based upon a review of these statistics, the model is most sensitive to changes in river conductance and agricultural recharge, and least sensitive to changes in storage coefficient or specific yield. Decreasing river conductance (which decreases the recharge to the aquifer) results in a ten-fold increase in the sum of squares over the calibrated model. The residual mean increases from 0.89 ft to 26.76 ft. Increasing the river conductance has a similar affect on model statistics.

6.10 RECOMMENDED MODEL APPLICATION VERIFICATION

The final step in a modeling project is usually model verification. Model verification is used to verify that the model adequately predicts aquifer responses. It is accomplished by running the model for a time period during which data are available for comparison. If the model can reproduce the data, it is considered calibrated and verified. If the model cannot reproduce the data, the calibration needs to be revised.

The ability of the CPM to predict future data has not been verified. It is recommended that the model performance is verified, but that this occur once additional data for 1996 through 2000 are assembled.

7.0 DATA GAPS

Although significant amounts of data were collected during the formulation of the FLM, the modeling effort also showed there are still gaps in data within the model area. These include:

- Well construction information for many of the wells in the area, including well depths and perforated intervals.
- Long-term aquifer test data for the entire basin, especially in the MAU.
- Bedrock location data for the northeastern portion of the CPM area.
- Better delineation of the bedrock elevations and water level contours in the area north of Indian School in the northwestern portion of the model.
- Better information on vertical gradients between the three units and whether the MAU and LAU are under confined conditions or are actually unconfined.
- Recharge rates from the Salt River.
- Land surface elevations for calibration targets.

1. Well construction information

Well construction information, including well depths and perforated intervals is not available for many wells in the area. This information may exist; it simply was not in the master files that WESTON reviewed as part of this project. In the future, as the need arises to refine areas within the model, WESTON recommends that the following sources are examined for additional data.

- The drilling logs on file with the state list the driller and contact information. Often drillers maintain well-organized files relating to holes they have completed. While perforation data may not have been transcribed to the well log filed with ADWR, the driller may still have it.

- Municipalities and irrigation districts frequently perform maintenance checks of their facilities. Although not common in the past, these checks now almost always include a video scan of the well. Perforated intervals and other construction information can be obtained from this scan. In addition, these scans can show areas of clogged perforations, affecting layers within the aquifer that are actually contributing to the well discharge.

- Municipalities and irrigation districts can be contacted and ADEQ could request to be informed when maintenance is scheduled for particular wells. If the pump is out of the hole for a sufficient period of time, ADEQ could arrange for a video survey to provide this information.

2. Long term aquifer test data for the CPM area, especially in the MAU

Long term aquifer test data are not regularly filed with any state agency. These data do exist, however, in several agency files and can be accessed.

- The Arizona Department of Transportation (ADOT) regularly conducted aquifer tests as construction wells were drilled during the freeway construction program through Phoenix. This data, however, is buried in the construction files at ADOT. Accessing it will require either contacting ADOT directly and gaining access to their files or contacting the contract hydrologist who conducted the tests and gaining access to their files.

- As was done with RID#104, municipal and irrigation district wells can provide the pumping source for long term tests as long as observation wells are available. In these cases, the selected well should have some form of flow monitoring device in place. We would recommend both a totalizing and instantaneous rate meter. The meter should be read and the flow data recorded on a regular basis. The distance between the observation wells and the discharge well should be surveyed. The time pumping starts and stops should be accurately recorded. Transducers will need to be installed in all wells.

- Ideally, observation wells should be located at different depths to provide information on vertical as well as horizontal conductivity.

3. **Bedrock location data for the northeastern portion of the CPM area and in the area north of Indian School in the northwestern portion of the model**

One of the most critical aspects of the CPM was the bedrock location in the northeast area and near the F&B facility. These areas are critical enough that geophysical testing would be in order. Wells are available to check the geophysical results. Accurate characterization of these bedrock highs would add significantly to the accuracy of future model results. Because of the urban nature of the setting, seismic testing is probably out of the question and normal electrical resistivity would have significant noise because of buried cables, pipes, etc. It is possible that Source Controlled Audio Frequency Magnetotellurics might work in this situation. While still a form of electrical resistivity, the electrical source can be set up miles from the target area and local interference is significantly damped.

4. **Better delineation of the water level contours in the area north of Indian School in the northwestern portion of the model**

Because of the number of high capacity irrigation wells in the area north and south of Camelback Road, it was very difficult to characterize the water levels in this area of the model, especially west of Central Avenue. This was further complicated by the F&B data. This is one area where future water level data collection efforts should be emphasized. As described later, it is important to determine the existence and extent of a third, confining layer in the UAU and accurate water level data could help significantly in that regard.

5. **Better information on water levels in and vertical gradients between the five (six) units. Determination of whether the MAU and LAU are under confined conditions or are actually unconfined; and, whether locally confined conditions exist within the UAU.**

One method of addressing this data gap would be to know the heads in individual layers within the aquifer. This can be accomplished through data gained from multiport wells and also from spinner logs that show the rate and direction of flow between units penetrated by a well. Seasonal water levels in piezometers completed in specific units would assist in addressing these issues particularly in the central portion of the model.

When new wells are constructed in the CPM area for ADEQ-related investigations, ADEQ can request that spinner logs be conducted as part of the well construction program. In addition, municipalities and irrigation districts can be contacted and ADEQ could request to be informed when maintenance is scheduled for particular wells. If the pump is out of the hole for a sufficient period of time, ADEQ could arrange for a spinner log to provide this information.

As facilities install monitor wells within the area of interest, ADEQ can request geophysical logs and that well nests be installed. The presence or absence of an intermediate confining unit in the UAU will impact contaminant movement.

6. Recharge rates from the Salt River

Significant effort has been expended to define the volume and extent of recharge from the Salt River. This effort has been hampered by the lack of historical data and the near- anecdotal nature of that which did exist. Although several reports were examined during the course of this investigation, the bulk of the data gathered dealt with the area east of Tempe Butte and not the CPM area. There may be opportunities to remedy this in the future; however, it will require coordination between several levels of government.

The City of Tempe recently completed their Rio Salado Project and filled the Town Lake. An inflatable dam impounds this lake. At some point in the future, lake management will, in all likelihood, call for the deflation of the dam and release of the lake water into the Salt River bed. The infiltration of that controlled release could provide valuable data for future model refinement.

7. Land surface elevations for calibration targets

The target wells used in model calibration were selected on the basis of number of years of water level measurement. Unfortunately, although water levels had been collected at these wells, more often than not, the elevation of the measurement point had never been surveyed. In these cases, that elevation was assumed to be land surface at the well location and that land surface were interpolated from USGS topographic maps. Based upon experience at other cites across the SRV, a properly surveyed elevation rarely matches that interpolated from a topographic map with the difference ranging from a few feet to easily half a contour interval plus the elevation of the measuring point. The elevations and locations of all the target wells should be surveyed.

8. Historical River Stage Data

In calculating recharge from the Salt River, MODFLOW uses river stage. No historical data uncovered to date has indicated how deep the water was during flow periods. In addition, no data were found related to the width of flow during these periods. Additional records may be available from the Maricopa County Flood Control District or in theses or research reports from the three state universities.

9. K data south of the river and north of McDowell

One problem encountered during calibration was that, although several aquifer tests had been conducted in the UAU through the central portion of the CPM, little data existed along the periphery, in particular south of the Salt River and north of McDowell road. It would be advantageous to arrange for the installation of nested piezometers near some of the larger wells in the area and to conduct aquifer tests using those wells.

10. Better definition of the extent of the MAU in the eastern portion of the model

In their SRV model, the ADWR showed the MAU extending well into the eastern portion of the valley. More recent work, however, has demonstrated that the MAU actually pinches out around 24th Street along the axis of the CPM. Additional research may be necessary to determine if this is a localized phenomenon or symbolic of regional conditions. Well logs in the northeastern model area show significant thicknesses of clay at depth that could be correlated with the MAU given additional data. This data could be gained from the logs of new wells constructed to address other data gaps.

11. Seasonal pumping for all wells in the area, not just RID

To date, only the RID has made monthly (and daily) pumping data available to the modeling team. The SRP and affected municipalities should be approached to provide similar data. At present, a major model assumption has been that SRP pumping mirrors RID. This may not be the case, especially in some areas where municipal wells may dominate the pumping scenario.

12. Delineation of a possible third layer in the UAU in the western portion of the model

Recently geologic evidence has been presented that suggests the presence of a third sub-layer in the UAU. This third layer is a seemingly continuous clay zone that produces confined conditions at some locations. Characterization of this third sub-layer could best be achieved using rotosonic drilling techniques to produce a continuous core of the materials encountered.

13. Canal Recharge

Although the CPM assumes the recharge received from irrigation canals was the same as calculated by the ADWR in the SRV model, more recent studies have demonstrated that canal recharge and the cessation of recharge due to canal lining may be significant on a local level. It is important that more accurate data be obtained from both the SRP and RID, although this may entail significant file research.

14. Exempt Wells

In the CPM model, exempt wells were considered deminimus and any water pumped by these wells was not included in the pumping file. Because exempt wells are non-reporting, no historic pumpage records exist. In fact, all that is really known about these wells is that someone took the time to register the well and pay the filing fee. CPM review comments from Dr. Thomas Maddock III pointed out that because these wells are normally shallow and near the Salt River, their pumping could easily intercept river recharge. In addition, because of the potential for a thin, shallow upper layer in the UAU, pumping by an exempt well in that layer could affect the path of migration of contaminants.

In the future, it would be advantageous to examine these wells more closely. A listing of exempt wells in the CPM area can be obtained from ADWR. These wells could be field checked to determine if they actually exist and, if they exist, if they still are equipped with pumps. If the well is equipped, some small amount of pumping can be assumed, or the owner could be contacted for additional information.

8.0 SUMMARY AND CONCLUSIONS

The CPM calibrates reasonably well. The mass balance error is 0.17 percent, the residual mean and ARM are 1 and 7.2 ft, respectively, and the residual standard deviation divided by the range in target values is 4 percent. The water level contour maps and gradients are similar in shape and direction of flow. In general, the differences between model calculated water levels and measured water levels are less than 10 ft. Differences greater than 10 ft appear to be caused by problems with data input to the model, either water level measurements or pumping rates and distribution with time.

However, there are areas in the model where additional data are needed to improve model calibration. These include the northwestern boundary area and the area of the Grand Canal near Indian School where model calculated water levels are higher than measured water levels. Model calculated water levels are lower than measured in the central part of the model area, an area that is of major concern for ADEQ. Additional data on pumping, land surface elevations and geology in this area will improve model calibration.

The CPM, as calibrated, fulfills the purpose of this project. It can be used to evaluate future remedial alternatives and provides a starting place for the evaluation of contaminant movement in the CPM area.

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Appendix D

Central Phoenix Plume Model
Phase III: Groundwater Flow
Model 1996-1998 Validation
Results Report Text

CENTRAL PHOENIX PLUME MODEL
PHASE III: GROUNDWATER FLOW MODEL

FINAL

1996 – 1998 VALIDATION SIMULATIONS

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ACRONYM LIST

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AF	Acre-feet
AMSL	Above Mean Sea Level
COP	City of Phoenix
CPM	Central Phoenix Plume Model
ft	foot, feet
HBU	Hydrologic Bedrock Unit
LAU	Lower Alluvial Unit
MAU	Middle Alluvial Unit
MAU_1	Upper Half of MAU
MAU_2	Lower Half of MAU
RID	Roosevelt Irrigation District
ROGR	Registry of Grandfathered Rights
SRP	Salt River Project
SRV	Salt River Valley
UAU	Upper Alluvial Unit
UAU_1	Shallower Portion of the UAU
UAU_2	Deeper Portion of the UAU
USGS	United States Geological Survey
WESTON	Roy F. Weston, Inc.
WQARF	Water Quality Assurance Revolving Fund
WWTP	Wastewater Treatment Plant
WVB	West Van Buren

Arizona Department of Environmental Quality
Central Phoenix Groundwater Model
Validation of Seasonal, Five-Layer Model

1.0 INTRODUCTION

The second phase in the development of a three-dimensional groundwater flow model for the Central Phoenix area was completed for the Arizona Department of Environmental Quality (ADEQ) in June 2000 (WESTON, 2000). The second phase consisted of the creation and calibration of a groundwater flow model. The area modeled encompasses the West Van Buren and former East Washington Water Quality Assurance Remedial Fund (WQARF) project sites from 56th Street on the east to 99th Avenue on the west, and from Camelback Road on the north to Dobbins Road on the south (Figure 1). The model simulated groundwater flow for 1972 through 1996.

The third phase of model development for the Central Phoenix area, the validation of the groundwater flow model completed in Phase 2, is documented in this report. The validation phase for the Central Phoenix groundwater flow model (CPM) included the compilation of the data for 1996 through 1998, the update of the model input arrays, and the simulation of the groundwater system using the five-layer, seasonal, transient, groundwater flow model.

1.1 OBJECTIVES OF THE VALIDATION MODELING

The validation phase is designed to evaluate the calibration of the CPM using new data. It tests whether the underlying assumptions used to develop the CPM (the conceptual model) and the simplifying assumptions used to develop the input data arrays are still valid when the model is run with a new data set. The calibration is validated if the model can reproduce the changes in water levels and flow directions in a reasonable fashion for a new time period using data that were not used in the model calibration. Reasonableness is evaluated by comparing the statistics generated from the calibrated model with the statistics generated from the model that uses datasets from 1972 through 1998, as well as comparing observed and simulated hydrographs and water level maps.

1.2 REPORT STRUCTURE

This report documents the tasks completed during the third phase of the CPM development. It is divided into six sections. Section 1 provides an introduction to the project. Section 2 provides a brief overview of the previous modeling phases, including the conceptual model and data used in the CPM development. WESTON has assumed that the reader is familiar with the previous work so details of the previous work are not provided. Section 3 describes the new data compiled and the validation process. Section 4 discusses the results of the validation simulations and model calibration. Section 5 discusses data gaps. Section 6 provides the summary and conclusions for the model validation phase.

1.3 STEPS IN THE CPM DEVELOPMENT

Phase 1 of the CPM development was the compilation of well, water level, pumping and hydrogeologic data into a series of spreadsheets. Phase 2 involved the creation of the CPM using the data compiled in Phase I. The creation of the CPM, a transient groundwater flow model for the Central Phoenix area, is the culmination of a project that began with the synthesis of a preliminary Conceptual Model in January 1998 (WESTON, 1998). The Conceptual Model, documented in a letter report to ADEQ, provided a summary of inflows and outflows to the model area. The second step in the modeling effort, a steady-state model, was documented in a letter report to ADEQ in July 1999 (WESTON, 1999a). The steady-state model provided information on the hydrologic system before major pumping stresses occurred. The third step was the development of a three-layer transient flow model to create the framework of the final CPM model. This effort was documented in a letter report to ADEQ completed in September 1999 (WESTON, 1999b). The final step in the model development was the modification of the three-layer model to create the calibrated, five-layer, seasonal groundwater flow model.

2.0 PREVIOUS PHASES IN THE CPM DEVELOPMENT

2.1 CONCEPTUAL MODEL

Land use in the CPM area was mapped using aerial photographs for 1976, 1988, and 1995. Predominant land uses within the project area are urban residential, office complexes, strip malls, and light industrial on the east and agricultural mixed with light industrial in the west. Details on the land use, and the subsequent sections on the development of the CPM Conceptual Model, are contained in *Central Phoenix Model, Phase II: Groundwater Flow Model, Final Documentation* (WESTON, 2000).

Groundwater flow regimes in the CPM area are dominated by regional pumping centers with recharge supplied from excess agricultural irrigation, canal leakage, and occasional flood events. Groundwater movement within the region is predominantly controlled by the areal distribution of recharge and pumping. Several geologic features, however, exert control over the direction of groundwater movement on a local scale. These include: the location and distribution of non-waterbearing formations; locally discontinuous and regionally extensive fine-grained or consolidated deposits, the "bedrock highs" in the eastern and north-central part of the model; and the presence of bedrock fault systems.

The alluvial basin of the Salt River Valley (SRV) consists of thick basin-fill deposits of unconsolidated to semi-consolidated Late Tertiary to Quaternary sediments that overlay the Hydrologic Bedrock Unit (HBU). These deposits are subdivided into three hydrogeologic units that comprise the regional aquifer in the SRV and are the primary focus of the modeling effort.

The Lower Alluvial Unit (LAU) overlies, or is in fault contact with, the HBU. The LAU consists mainly of conglomerate. The Middle Alluvial Unit (MAU) overlies the LAU and is predominantly silt and clay with interbedded sand and gravel lenses derived from surrounding mountains. The unit is absent in the eastern basin area, yet reaches thicknesses of 1,600 feet along its axis. The Upper Alluvial Unit (UAU) extends from land surface to the top of the MAU and consists mainly of silt, sand, and gravel deposited during the final stages of development of the alluvial basin. The UAU is typically between 200 and 500 feet thick in the CPM area. The UAU and MAU were each split into two layers for the CPM. The UAU was divided at a point where the uppermost sands and gravels graded into clayey sands with apparent clay content greater than 30 percent. The MAU was split in half.

Water in the UAU was considered unconfined. It was assumed that the MAU and LAU are both confined systems. There are three years with basinwide water level data collected over a short time period: 1972, 1982, and 1991 (WESTON, 2000).

The transmissivities reported in the literature were converted to hydraulic conductivities by dividing the transmissivity by the saturated thickness penetrated by the well and, preferably, the well screen. The calculated conductivities were plotted on the CPM base map and zones of apparently equal (order of magnitude) aquifer properties were developed. The hydraulic conductivity in the UAU ranges from 5 to 700 ft/day; the range for the MAU is 7 to 30 ft/day; the range for the LAU is 3 to 20 ft/day.

Groundwater pumpage represents the major outflow from the groundwater system within the CPM study area. The annual pumping data were obtained from the primary agencies that withdraw the water [Salt River Project (SRP) and Roosevelt Irrigation District (RID)], from the Registry of Grandfathered Water Rights (ROGR) database, from the Arizona Department of Water Resources (ADWR) files for the SRV, and from the facility files.

The Salt River is the main channel for surface runoff and a source of recharge to the groundwater. Recharge from infiltration of flood flows along the Salt River does not significantly change the subsurface flow directions regionally but may cause local increases in groundwater elevations immediately adjacent to the channel.

In much of the western portion of the CPM, irrigated agriculture remains the dominant land use. The agricultural recharge rate used in the SRV model varied by area but averaged 0.92 feet per year. This value was used initially in the CPM but was revised during model calibration to 1.82 feet per year to match available data.

The infiltration rates for the canals and laterals within the CPM area were taken directly from the Salt River Valley model (Corkhill, et al, 1993). The Salt River Project (SRP) and the Bureau of Reclamation developed the rates for lined and unlined canals. The canal recharge rates in the CPM were calculated based on when the canal was lined, and on the percentage of the canal present in a model node. Recharge from canal laterals was not explicitly modeled.

2.2 MODEL DEVELOPMENT

The CPM's purpose is to evaluate the effect of proposed remedial alternatives on the groundwater flow system. Therefore, the time period of most interest to ADEQ is the 1990s and later. Based on the model purpose, the pumping distribution, and the water level data, the beginning time for the CPM was picked as January 1, 1972. This starting date provides an 18-year period during which the effects derived from starting the model under transient conditions are ameliorated and provides sufficient time prior to 1990 to examine the changes in the aquifer resulting from pumping.

The CPM uses a uniform grid of 80 rows by 144 columns. Nodal spacing is 660 ft. The five hydrologic units modeled are the two layers comprising the Upper Alluvial Unit (UAU_1, UAU_2), two layers within the Middle Alluvial Unit (MAU_1, MAU_2) and a portion of the Lower Alluvial Unit (LAU).

The CPM uses both MODFLOW (McDonald and Harbaugh, 1988) and MODFLOW-SURFACT (version 1.2) (HydroGeoLogic, Inc., 1996) to solve the equations that define groundwater flow. SURFACT includes several enhancements and additional packages that have been added to the standard MODFLOW program. These include the ability to reallocate pumping from wells that tap multiple layers in the case where shallower layers dewater and the pumping needs to be reapportioned between deeper, saturated layers. It also includes a revised resaturation calculation and provides the ability to automatically recalculate time step parameters, which aids in model convergence.

The CPM simulates flow from January 1, 1972 through December 31, 1996 for a total of 25 years. Each year is subdivided into three unequal stress periods with from 7 to 10 time steps per stress period. The number of time steps per stress period is determined by the adaptive time step package in SURFACT based on parameters set by the user and the model convergence during each time step. The length of each stress period was determined by reviewing monthly pumping data provided by RID for 1992 through 1998. Summing all of the data by month showed the following distribution of pumping:

January & February: 10% annual pumping
March - September: 84% annual pumping
October - December: 6% annual pumping

These percentages were used to set the length of each stress period in a year. Stress period 1, January and February, is 59 days long. Stress Period 2 is 214 days long. Stress Period 3 is 92 days long.

There are three types of flow conditions along the model boundaries within the CPM: areas with time-variant flow and heads, areas with constant flow and head, and areas with no-flow across the model boundaries. Time variant flow and heads occur along the northwestern, western and southwestern model boundaries. The eastern, northeastern and south-central areas of the CPM have constant flow. One-third of the southern boundary, adjacent to South Mountain, is considered an impermeable boundary resulting in no flow into or out of the model area.

2.3 CPM CALIBRATION

The mass balance error for the calibrated CPM was 0.17 percent. As expected, the major outflow from the model is from pumping. Outflow across the model boundary is an order of magnitude less than pumping. The major recharge mechanism is from the infiltration of irrigation water and canal seepage with the second highest source from the river.

The CPM computed water level contours in general match the shape and direction of flow. However, model computed heads were higher than measured in the eastern and midwestern model area and lower than measured in the central portion of the model area (WESTON, 2000).

The model appears to function reasonably well along the river and along the model interior in the area of most concern to ADEQ. Differences in modeled and observed data are less than 10 feet in most areas where pumping does not occur.

Based upon a review of the model statistics from the sensitivity analysis, the model is most sensitive to changes in river conductance and recharge, and least sensitive to changes in storage coefficient.

3.0 CPM VALIDATION

The evaluation of model validation uses the existing model framework with data from a time period that was not simulated in the original model studies. By running the model with new data, the user can evaluate how well the model is calibrated. The CPM validation process consisted of three tasks: the compilation of new data, the modification of the model input arrays, and the simulation of the Central Phoenix area using the CPM model with the updated model arrays. The validation period selected for the CPM was 1996 through 1998. Although the CPM calibration period included 1996, pumping data had only been available for the first six months of 1996.

3.1 COMPILATION OF DATA

The new data needed for the validation included pumping data, recharge from irrigation as well as from the Salt River, canal lining information, and water level data for the period 1996 through 1998.

3.1.1 Pumping Data

Pumping in the calibrated CPM was from 335 non-exempt wells. Pumping rates varied with time. The first subtask, then, was to obtain the ROGR database pumping files from the ADWR for the last six months of 1996 and all of 1997 and 1998. The data were obtained electronically, but they had to be converted to the model spreadsheet format. During the conversion process, WESTON discovered that the 1996 pumping data for RID was missing from the ADWR ROGR database. ADWR was informed of the problem and WESTON contacted RID directly for the correct pumping information.

3.1.2 Review of Seasonality

The seasonality in the CPM was defined using the monthly pumpage from several RID wells. The other major pumper in the CPM area is the SRP. The primary source of the irrigation water provided by SRP to users is from surface water, but groundwater is pumped to augment the surface water supply. WESTON had been unable to obtain the monthly pumping for the SRP wells within the CPM area during the development of the original model, but SRP provided the data for this phase of the modeling.

Monthly pumping volumes were provided for 60 wells within the CPM area (Appendix A). Assuming the same temporal distribution used for the RID wells, the percent of the total annual pumping that is pumped during that time period from the SRP and RID wells is shown in Table 1.

Table 1. Distribution of Annual Pumping for SRP and RID Wells

Period	SRP Pumping	RID Pumping
January & February	8%	10%
March – September	77%	84%
October - December	15%	6%

Although the SRP data showed less pumping than RID during the March through September period, and more pumping than RID during the October through December stress period, the distribution agrees reasonably well with the original CPM distribution developed using the RID data, so WESTON chose to not change the distribution of pumping seasonally. The difference in the two distributions could cause the simulated drawdown in the SRP wells to be greater than measured during the second stress period and less than measured during the third stress period.

3.1.3 Canal Lining

The Salt River Valley Water User's Association has three irrigation canals that transmit water within the CPM area, the Arizona Canal, Grand Canal and Western Canal. Although the majority of the channels of the Western and Arizona Canals are lined, there are several reaches of the Grand Canal that are unlined. The SRP was contacted regarding lining of the Canals since 1996. SRP provided a map showing the status of the canal lining as of 2000 (Appendix B). There were no changes between the last model simulation period and the 2000 map.

3.1.4 Water Level Data

Water level elevation data are used to evaluate the model validation. This is accomplished by comparing hydrographs of model-simulated water levels with measured water levels and by comparing water level contour maps. Data had been assembled through 1996, but numerous monitor wells were installed during 1997 and 1998. WESTON obtained water level data from the ADWR, from ADEQ facility files, and from BE&K-Terranext, the ADEQ Contractor for the West Van Buren WQARF site. ADEQ had instituted a monthly water level monitoring task for the West Van Buren area in 1997 and had also installed nine transducers in three sets of nested wells. The wells monitored by ADEQ were chosen using two criteria:

- Locations not currently monitored where calibration data were needed, and
- The wells were completed in only one hydrologic unit.

The data used to create water level maps during the original model development were, in many cases, composite water levels for several hydrologic units. Many of the wells are screened across the UAU as well as the MAU. Problems with using the composite data are illustrated very well in the transducer data for the three sets of nested wells, Figures 2 through 4. These data show that the UAU and MAU water levels may be similar when wells are not pumping, but that water levels quickly diverge once pumping begins.

The nested wells are generally completed in the shallow UAU, deeper UAU, and the shallow MAU. All of the well nests show a similar response to pumping throughout the year. The deeper wells show minimal response to pumping while the deeper UAU wells show the most response to pumping. The shallow UAU wells show a moderated response to regional pumping, but may also show a significant response to localized pumping in the vicinity of the well.

The data used to create the water level maps for this phase of the modeling are for the shallow UAU. All of the available data were used to create hydrographs and entered into the model as calibration targets.

3.1.5 Salt River Flow

The previous work determined that a flow of 320,000 AF per year at Granite Reef Diversion Dam probably resulted in flow in the Salt River within the CPM area and possible recharge to the groundwater system. Flow at Granite Reef Dam during 1996 through 1998 was less than that threshold value, so it was assumed that there was no recharge to the groundwater system.

3.1.6 Land Use

The types of land use within the CPM area had been used to establish the recharge rates to the groundwater system. Review of a 1999 aerial photograph did not show any significant changes in land use within the CPM area since 1995, the last time period that land use was reviewed for the calibration model. The recharge rates and distribution of the rates from the 1995 period were used for the validation model.

3.2 MODIFICATION OF DATA ARRAYS

The input data arrays were developed for the CPM under Phase II of the model. The MODFLOW and MODFLOW-SURFACT packages used in the CPM are described in Table 2.

3.2.1 Pumping Spreadsheet and Input Data

An Excel spreadsheet with the annual pumping volumes for wells within the CPM area had been created in Phase I of the of the model. The spreadsheet was updated to include the pumping volumes from 1996 through 1998 (Appendix C). The data in this spreadsheet were extracted and formatted to create a Fracture Well package input file for 1972 through 1998.

In addition, an Excel spreadsheet was created with the monthly pumping volumes for the SRP irrigation wells (Appendix A). The data were used to evaluate the distribution of SRP pumping with time throughout the CPM area.

3.2.2 Recharge

The recharge rates in the CPM model are based upon the type of land use within the area. Because the review of the aerial photograph for 1999 showed that land-use between 1995 and 1999 had not changed significantly, the only modification to the Recharge data file was to apply the recharge rates used in 1995 through 1998.

Table 2: MODFLOW/SURFACT Packages Used in the CPM

Package Title	Abbrev.	MODFLOW	MS	Modified for Validation	Purpose	Input File	Name
						Calibration	Validation
Basic	BAS	X		Yes (Number of Stress Periods)	Assigns data that are used by the program for the entire model. Data include definition of boundaries, initial determination of time step length, initial heads, and printing results.	116sf.bas	cpmval01.bas
Block Centered Flow 4	BCF4		X	No	Calculates the terms of the finite-difference equations for flow from node to node and flow into storage. Defines model grid dimensions and whether the model is steady state or transient. Data read include hydraulic conductivity, layer top and bottom elevations, and storage coefficient/specific yield. SURFACT modifications to the standard BCF package include a more rigorous treatment of variably saturated flow.	116sf.bcf	116sf.bcf
General Head Boundary	GHB	X		Yes (Boundary Heads)	Reads the data for the calculation of inflow or outflow at the General Head Boundaries and adds the terms to the finite difference equations.	116sf.ghb	cpmval01.ghb
Recharge and Seepage Face	RSF4		X	No (Same rates used for previous periods)	Reads the data for the calculation of recharge and adds the terms to the finite difference equations. Although the SURFACT package is used, only the standard recharge calculations from MODFLOW are used.	116sf.rch	cpmval01.rch
River	RIV	X		Yes (No river flow during 1996-1998)	Reads the data for the calculation of recharge or discharge from the River and adds the terms to the finite difference equations.	116sf.riv	cpmval01.riv
Well	WEL	X		No	Reads the data for the calculation of flow from wells that are used as in the CPM as constant flow boundaries and adds the terms to the finite difference equations	116sf.wel	cpmval01.wel

Package Title	Abbrev.	MODFLOW	MS	Modified for Validation	Purpose	Input File Calibration	Name Validation
Fracture Well	FWL4		X	Yes (Additional pumping)	Reads the data for the calculation of flow from multi-layered wells and wells that may be over pumped. This package provides a mechanism for the program to reallocate pumping from dewatered layers to deeper, saturated layers. The terms are added to the finite difference equations.	116sf.fwl	cpmval01.fwl
Adaptive Time Step and Output Control	ATO		X	No	Reads the data that permits adaptive time-stepping schemes with automatic controls of time step sizes. This package allows the simulation to proceed more efficiently by recalculating time step sizes if convergence occurs either too quickly or not quickly enough.	116sf.ato	cpmval01.ato

3.2.3 River

The River package is one method of describing recharge from the Salt River to the groundwater system. The Salt River was simulated in the CPM by active river nodes when flow at Granite Reef Dam exceeded the threshold value. Because the threshold value was not exceeded from 1996 through 1998, there were no active river nodes except below the City of Phoenix Wastewater Treatment Plants at 23rd Avenue and 91st Avenue.

3.2.4 Target Water Levels

One of the means by which the CPM calibration is evaluated is through the comparison of measured water levels with those calculated by the model. The new water level data were entered into the water level spreadsheet created during Phase I of the CPM (Appendix D). The hydrographs created during the original model calibration were updated with the new data and new hydrographs were also created for the monthly monitoring well network established by ADEQ in 1997 (Appendix E).

The data were also used to create seasonal water level maps for January 1998 (Figure 5), April 1998 (Figure 6), October 1998 (Figure 7), and January 1999 (Figure 8). The differences between water levels were also calculated and plotted for the periods January to April 1998 (Figure 9), April to October 1998 (Figure 10), October 1998 to January 1999 (Figure 11), and January 1998 to January 1999 (Figure 12). These maps show the changes in water levels seasonally. They also very dramatically show the affect of new, layer specific water level data north of the Grand Canal and in the northeastern portion of the model where elevations are higher than used in the original model.

Two new target water level files were created for import into Groundwater Vistas to evaluate the calibration of the model. The first file used all of the data measured since 1972. The second file contained only the data from 1996 through 1998.

3.3 MODEL SIMULATIONS

The final CPM simulation during the calibration process was 118sf. The dataset from this run was modified using the files described in the previous section. The data arrays describing the hydrologic parameters for each layer, layer definitions, model grid, boundary conditions, division of the year into stress periods, and solution parameters remained the same as those used in 118sf. This permitted an evaluation of the framework of the model. MODFLOW-SURFACT was run using the validation data arrays and a validation model, CPMVAL01, was created. The model was run only once.

After completion of the model simulation, the calibration statistics, flow directions and gradients, and model mass balances were compared to evaluate the robustness of the CPM.

4.0 EVALUATION OF MODEL CALIBRATION

Model calibration is a measure of how well the model simulates the hydrologic system. The model calibration for the CPM occurred over a 25-year period from 1972 through 1995. This calibration, although reasonable, was based upon composite water level data with much of the data from irrigation wells. The newer data set collected by ADEQ provided the opportunity to evaluate the model calibration using a more selective data set.

The calibration was evaluated using:

- a comparison of measured and simulated water levels,
- statistics showing the variation in the measured and simulated water levels,
- the model mass balance,
- groundwater flow directions and gradients, and
- the comparison of measured and simulated water levels with time using hydrographs.

4.1 COMPARISON OF MEASURED AND SIMULATED WATER LEVELS

Ideally, the slope of the regression line that is calculated for a scatter plot of the observed versus simulated water levels should have a slope of 1.0, which means the data should fall on a line that has an angle of 45 degrees. The slope of the line for 118sf was 0.988 (Figure 13), indicating that the model simulated data corresponded well to the observed data with a slope close to 45 degrees. The slope of the line for CPMVAL01 for all data for 1972 through 1998 (Figure 14) is not quite as good as the relationship demonstrated by 118sf as demonstrated by a slope of the regression line of 0.938 versus 0.988, respectively.

One area of the model that greatly influences the slope of the regression is in that area where observed head values are greater than 1150ft AMSL (Figure 14). The CPM is not simulating water levels in this area very well. These data are from three observation wells: MOT021, AEW01-18, and ADEQ-08. All three wells are located in the northeast portion of the model close to the model boundary in an area where the hydrologic bedrock is shallow.

If data from these three wells are removed (Figure 15), the slope of the regression line is 0.975, which is closer to the 118sf value of 0.988.

4.2 MASS BALANCE

The cumulative mass balance error of CPMVAL01 is 0.17 percent (Table 3). This is the same value generated in 118sf. The mass balance error is considered reasonable for this type of model.

Table 3: Cumulative Mass Balance for CPM Validation Run, CPMVAL01

	CPMVAL01 (cu ft)
IN	
Storage	0.85672E+11
Constant Head	0.00000E+00
Fracture Well Storage	0.12584E+06
Fracture Wells	0.11612E+10
Wells	0.25562E+11
Recharge	0.11159E+12
River Leakage	0.98390E+11
Head Dependant Boundaries	0.34544E+11
Total In	0.35692E+12
OUT	
Storage	0.87802E+11
Constant Head	0.00000E+00
Fracture Well Storage	0.13224E+06
Fracture Wells	0.19766E+12
Wells	0.10462E+07
Recharge	0.00000E+00
River Leakage	0.34942E+09
Head Dependant Boundaries	0.70491E+11
Total Out	0.35630E+12
In-Out	0.61833E+09
Percent Discrepancy	0.17

While this value is acceptably small, some of the individual stress period mass balance errors in CMPVAL01 (and in 118sf) were larger, with the largest being 11.5 percent. WESTON believed these errors were caused by the automatic time step parameters set in the input files. WESTON tested this theory by running the model using different time step multipliers. The four different multipliers showed that a time step multiplier of 1.4 yielded the lowest cumulative mass balance error (0.12 percent). This run also had the smallest maximum stress period mass balance of 5.9 percent. These time step parameters were not used for the validation because the objective of the validation was to compare the model results, assuming the model remained the same. It is recommended that any future simulations evaluate the time step parameters and use the parameters that result in the smallest mass balance error.

Table 4: Model Statistics

	CPMVAL01	118sf
Model		
Time Step Multiplier	1.6	1.6
Cumulative Mass Balance Error (percent)	0.17	0.17
Model Statistics		
Residual Mean (ft)	2.622	1.039
Residual Standard Deviation (ft)	9.976	9.326
Sum of Squares	219,611	105,148
Absolute Residual Mean (ft)	7.122	7.216
Minimum Residual (ft)	-37.327	-37.327
Maximum Residual (ft)	58.037	34.845
Head Range (ft)	318.31	215.5
Standard Deviation/Head Range	0.031	0.043

4.3 QUALITATIVE COMPARISON OF WATER TABLE MAPS

The January 1998 and January 1999 simulated versus measured water table contours were compared (Figures 17 and 18). The January 1998 (Figure 17) simulated water level contours correspond reasonably well with the contours drawn using the measured data map with respect to gradient direction and magnitude. The exceptions occur in the area north of the Grand Canal and to the west of I-17 and in the northeastern portion of the model. The discrepancy in simulated and observed water levels along the northern boundary is caused by the additional layer-specific water level data that showed that groundwater elevations in this area in the upper UAU are higher than previous maps indicated and that the shape of the contours is more complicated than previously thought. WESTON identified a “ridge” in groundwater elevations in this area (WESTON, 1999c). This “ridge” can be seen in the January 1999 contour map. Additional data in Central and Camelback area and in the West Central Phoenix area show that there are differences in water levels and in the direction of flow between the shallow UAU and the deeper UAU. These differences are not simulated by the CPM.

Although flow direction and gradients are similar in the central portion of the model, in general, water levels are 10 feet too low.

The comparison of the January 1999 simulated and observed water level contours (Figure 18) also shows general agreement between gradient directions and magnitude except, as with the January 1998 map, the area north of the Grand Canal, and an additional area along the central southern border. The discrepancy along the northern border is most likely due to the same reason as previously mentioned, namely the identification of an area with higher then previously known water elevations. The “ridge” is apparent in the January 1999 measured map. The discrepancy in the southern portion of the model is most likely due to the lack of measured data in the shallow UAU in this area. As mentioned previously, the observed water table maps were constructed using only data from the shallow UAU.

4.4 MODEL STATISTICS

As discussed in the CPM report, GWV calculates certain statistics on the residuals that aid in the evaluation of model calibration (Table 3). These include:

- Sum of squared residual
- Residual mean
- Residual standard deviation
- Absolute residual mean
- Residual standard deviation divided by the range in target values

The sum of the squared residuals is used during the calibration process to evaluate the changes in residuals as calibration proceeds. One of the goals during calibration is to minimize the sum of the squared residuals. The underlying assumptions in this comparison are that the number of targets and the simulation time period have not changed between calibration model runs.

The assumptions are not true for the validation run because the time period has increased with a resultant increase in the number of targets. The comparison of the sum of the squared residuals has no value in this case because the number of residuals has increased between 118sf (1194) and CPMVAL01 (2064) as new calibration targets were added. The number of targets increased 870, a 72% increase in the number of points.

The residual mean for CPMVAL01 is 2.62 versus 1.03 for 118sf (Table 3). This indicates that the model-simulated water levels are lower than observed water levels. The largest positive residual increased from 34.8 ft in 118sf to 58.0 ft in CPMVAL01. The larger positive residuals come from wells in the northeast corner of the model near the boundary. Ideally, the residual mean should be close to 0, indicating that the magnitude of the positive residuals is similar to the magnitude of the negative residuals.

The absolute residual mean decreased slightly from 7.2 to 7.1. The absolute residual mean is calculated by taking the absolute value of each residual and then calculating the mean.

The residual standard deviation increased from 9.3 to 9.9. This is an indication that the range of residuals increased. This is also reflected by the increase in the maximum positive residual from 34.8 to 58.0.

The residual standard deviation divided by the range in head decreased from 0.043 to 0.031. This is caused by the increase in the range in head from 215 to 318 ft. It is an indication that the range of residual values is small compared to the overall change in head in the model.

4.5 HYDROGRAPHS

Ten hydrographs were discussed in the original CPM report. These same ten hydrographs are discussed here along with four additional hydrographs to evaluate the years 1997 through 1999.

RID-110 (Figure 19) continues to be one of the best hydrographs. Comparing the 118sf hydrograph (Figure 20) to the CPMVAL hydrograph clearly shows the effects that the incorrect RID pumping totals in 1996 had on the model. The calibration model only had pumping rates for the first six months of 1996 for most pumping wells. Pumping was missing from ADWR CD for RID for 1996, so all RID wells show no pumping in 1996 in the calibration model. The model generated hydrograph for the calibration model shows water levels rising during the last six months of 1996 when the measured data show water levels declining. The model predicted water levels match the measured data better once the total pumping for 1996 is included in the validation model. The CPMVAL hydrograph shows decreasing water levels during 1996 with the additional water level data points matching the simulated water levels.

SRP-048 (Figure 21) contains only one additional data point. This point matches well with the simulated data.

GOM-3 (Figure 22) contains only one additional data point. The additional data point continues the trend of observed water levels higher than simulated water levels.

SRP-082 (Figure 23) contains only one additional data point. As with GOM-3, the additional data point continues the trend of observed water levels higher than simulated water levels.

MAS-1 (Figure 24) contains two additional data points that continue the pattern of general agreement between observed versus simulated with the observed water levels being higher than the simulated.

The additional validation data for ALL-021 (Figure 25) indicate a continuing decline in water levels. This decline is seen in the simulated data, but the simulated water levels continue to be approximately 5 to 6 ft too high.

The effect of the corrected RID pumping values is seen in the AVB46-01 (Figure 26) hydrograph, with water levels declining from 1996 to 1997 in the validation versus increasing in the original simulation (Figure 27). The simulated data now display a similar trend in water levels throughout 1996.

Additional data for COP-338 (Figure 28) display declining water levels from 1995 through 1999. Again, with the corrected pumping data, the simulated data display a similar trend, although about 5 to 6 ft too low.

The simulated data show good agreement with the two additional data points for SRP-047 (Figure 29).

Four additional hydrographs, AVB10-02, AVB37-01, AVB47-01, and AVB60-01, were chosen to show the model calibration at locations without data during the original model calibration.

Simulated water levels at AVB10-02 (Figure 30) are generally similar or lower than observed levels, with the largest difference occurring during the years 1995 and 1996. The timing of the simulated seasonality agrees with observed data for 1997 and 1998, but the magnitude is not reproduced. This could be because the model uses an average pumping rate applied to the entire season. The model-simulated drawdowns are an average for the pumping period as compared to observed data that might reflect more intense, shorter duration pumping producing larger drawdown.

AVB37-01 (Figure 31) displays a seasonal trend that is similar to that shown in AVB10-02, namely the simulated water levels reproduce the timing of the seasonality but not the magnitude.

Simulated water levels for AVB47-01 (Figure 32) are initially too high during 1993 and 1994, but appear to be too low for 1995 through 1996. The trend in water levels in 1997 and 1998 is similar to that observed in the previous hydrographs. It is possible that if monthly water level measurements had been taken during 1995 and 1996 that a similar pattern would have existed, strengthening the correlation.

The timing of the seasonality of AVB60-01 (Figure 33) is offset slightly compared to the previous hydrographs discussed. This offset indicates that the assumptions used to define the seasonal pumping may not be valid for this region.

The hydrographs for AVB69-01 (Figure 34) and ABV69-02 (Figure 35) show definite responses to pumping in nearby wells. However, the magnitude of the change in water levels in AVB69-01, the deeper well, is as much as 45 ft from 1997 through 1998, while the model predicted water levels would show only 10 ft of change. The shallower well, AVB69-02, shows less than 30 ft of change in water levels, with the model predicting less than 10 ft difference.

The differences in observed water levels in the two wells shows that the shallower UAU and deeper UAU respond differently to pumping. This difference between the model simulated and observed water levels indicates that the CPM does not simulate the different responses in this area. These two wells demonstrate the problem with creating a transient model when limited data are used for calibration. Although water levels in both wells are similar when nearby wells aren’t pumping, they differ by more than 15 ft when wells are pumping.

4.6 VERTICAL GRADIENTS

The direction of flow and magnitude of vertical gradients between the hydrologic units within the CPM area has not been well documented. It is only since the late 1990s that nested wells and piezometers have been installed within the area, but the frequency of the collection of water level data has been limited which limits the ability to evaluate the vertical gradients with time. ADEQ recognized the limitations in the existing data set and installed three sets of nested wells and instrumented the three sets of wells with pressure transducers to measure water levels on a regular basis. The data from these piezometers showed some unexpected results that impact the use of water level data for model calibration.

AVB78 had three screened intervals denoted by 01, 02, and 03 (Figure 2). AVB78-01 was interpreted as being in the UAU, AVB78-02 was interpreted as being in the MAU, and AVB78-03 was interpreted as being in the MAU (HSI, 1999). It is evident from the data that the vertical gradient in the area of AVBV-78 is highly variable over short time intervals. It appears that during the winter, non-pumping season vertical gradients are near 0. During the summer pumping season, the difference in the water level elevation is close to 25 ft with the screen interval of 561-581 ft bgs (the middle interval) displaying the greatest response. During the times of maximum vertical gradient, the gradient is upward from AVB78-03 to AVB78-02 and downward from AVB78-01 to AVB78-02.

This points out the problem of trying to calibrate the model to a less complete hydrographs (i.e., data that was collected more intermittently).

It is clear from Figure 2 that water levels in AVB78-01 and AVB78-02 behave in a similar fashion, and water levels in AVB78-03 behave in a more independent manner. This leads to the likely possibility that AVB78-01 and AVB78-02 are completed in the same unit and AVB78-03 is completed in a separate unit. This is not consistent with HSI interpretation that places AVB78-01 in the UAU and AVB78-02 and AVB78-03 in the MAU.

AVB79 is also a series of three nested piezometers (Figure 3). As with AVB78, the AVB79 data indicate a vertical gradient that is highly variable in time again pointing out the need for temporally complete datasets when trying to interpret vertical gradients and incorporate the information into model calibration. The main feature of the AVB79 dataset is that water levels behave independently in all three screened intervals even though published reports indicate that AVB79-01 is in UAU and AVB79-02 and AVB79-03 are both in the MAU. AVB79-01 displays a high frequency variability of approximately 3 to 4 ft, possibly due to a domestic well cycling on and off. AVB79-02 displays a signal more consistent with pumping of large irrigation well. AVB79-03 shows little variation indication that it is probably completed in a separate unit than AVB79-02.

The AVB69 data set again displays a pattern of a variable vertical gradient with time with the difference in water levels elevations ranging from 0 ft during the winter, non-pumping times to greater than 15 ft during the summer pumping season. The deeper of the two intervals shows the greater response.

5.0 DATA GAPS

The validation phase of the modeling confirmed the data gaps identified during the development of the CPM.

These data gaps included:

1. Well construction information for many of the wells in the area, including well depths and perforated intervals.
2. Long term aquifer test data for the entire basin, especially in the MAU.
3. Bedrock location data for the northeastern portion of the CPM area.
4. Better delineation of the bedrock elevations and water level contours in the area north of Indian School in the northwestern portion of the model.
5. Better information on vertical gradients between the three units and whether the MAU and LAU are under confined conditions or are actually unconfined.
6. Recharge rates from the Salt River.
7. Land surface elevations for calibration targets.

The evaluation of the water levels collected using the transducers in the nested wells showed that items 1, 5 and 7 are extremely important in determining movement between the three units, but also showed that the existence of vertical gradients within the model area is highly dependent on pumping rates and the proximity of pumping wells to the monitor well location. The data showed that the water levels for the shallow and deep UAU and MAU may start at the same elevation when there isn't pumping in the system, but the three units respond differently to the pumping. The CPM was calibrated against a data set that contained composite water levels and both static and pumping water levels. However, the relationship between water levels at different depths when nearby wells pump was never well defined. The new nested well data indicates that the calibration of the CPM using the 1972 to 1996 data, although reasonable, may have resulted in some areas of the model where the vertical conductance between the units is overestimated and the horizontal hydraulic conductivity is underestimated.

The hydrographs generated from the monthly data collected by ADEQ from the water level monitoring network for both West Van Buren and West Central Phoenix demonstrated the importance of collecting a complete data set with time. Water levels in wells not affected by pumping may vary as much as 15 feet over a year. If model calibration were conducted against only one or two data points from a monitor well, the magnitude of the response would not be simulated, and although the model could be calibrated against the smaller data set, in reality the model simulated water levels could be as much as 15 feet different than the water levels in the aquifer.

In addition to the seven data gaps originally identified in the CPM calibration documentation, one more should be added. Monthly water level measurements in the monitor well network identified by the West Central Phoenix Project and the West Van Buren Project should continue until a major flow event occurs in the Salt River (defined as flow at the Granite Reef Dam greater than 320,000 AF/yr).

The use of transducers in selected nested wells should continue so that the hydraulic relationship between the shallow and deeper UAU and the shallow and deeper MAU is more clearly defined. The transducers should remain in place until a major flow event occurs in the Salt River.

Data from the recent rounds of water level measurements also show that water levels along the northern boundary of the model are more complex than originally assumed in the CPM, and that the recharge from the Grand Canal has a major impact on shallow water levels, but less of an impact on deeper water levels. It is unclear whether other Canals in the valley have a similar impact. Canal lining has had a major impact on water levels and proposed remedial strategies at sites near the Grand Canal. Ongoing work on site-specific models will provide data that can be used to modify the CPM and refine model calibration.

6.0 SUMMARY AND CONCLUSIONS

The calibration of the CPM is still reasonable given the newer data set used in the validation simulation. The mass balance error is 0.17 percent, the same error for the original model. The residual mean and absolute residual mean are 2.62 and 7.12 ft, respectively, compared with 1 and 7.2 ft, respectively, for the original model. The residual standard deviation divided by the range in target values is 3 percent, lower than the original model 4 percent.

The water level contour maps and gradients are similar in shape and direction of flow. In general, the differences between model-calculated water levels and measured water levels are less than 10 feet. Differences greater than 10 feet appear to be caused by problems with data input to the model, either water level measurements or pumping rates and distribution with of pumping time.

Although data from nested piezometers or wells with limited screen depths weren't available for the validation runs, data for the 1999 time period show that vertical gradients are strongly influenced by the rate of pumping and the proximity to a pumping well. The vertical gradients change with time and flow directions may reverse depending on activity within an aquifer.

There are areas in the model where additional data are still needed to improve model calibration. These include the northwestern boundary area, the northeastern area and the area of the Grand Canal near Indian School where model calculated water levels are higher than measured water levels. Model calculated water levels are lower than measured in the central part of the model area, an area that is of major concern for ADEQ. Additional data on pumping, land surface elevations, geology and vertical gradients in this area will improve model calibration.

The CPM, as calibrated and validated, fulfills the purpose of this project. It can be used to evaluate future remedial alternatives and provides a starting place for the evaluation of contaminant movement in the CPM area. Additional data collect efforts and results from site-specific modeling will help to refine the CPM calibration with time.

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